Volume 3 November 1957 No. 9

Canadian Aeronautical Journal

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OTTAWA

Operation Call and Haul

During Exercise "Call and Haul" at Fort Riley, Kansas, 15 U.S. Army Otters of the 2nd Company moved 305 fully equipped combat troups of the 16th Infantry a distance of 35 miles in 80 minutes.

Subsequently, 10 Otters shuttled 20 tons of ammunition and supplies into an improvised "battle field" landing strip in a 45 minute period.

The Otter carries a crew of two—over a ton of payload—lands in less than 600 feet.

8-57

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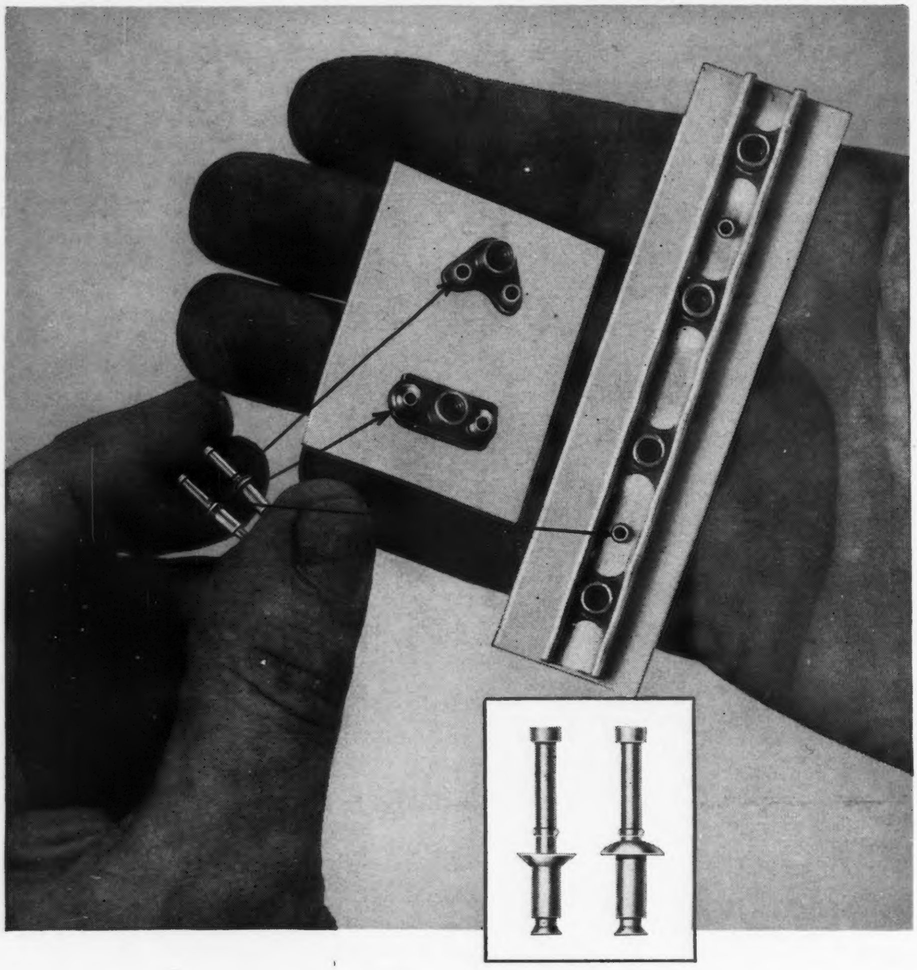

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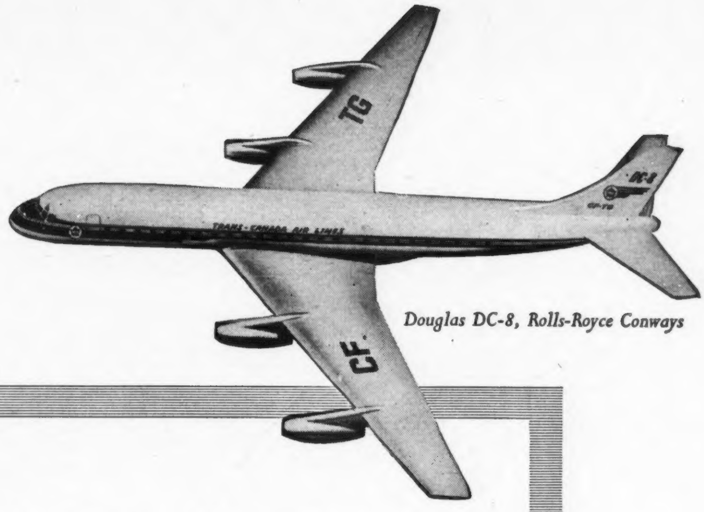

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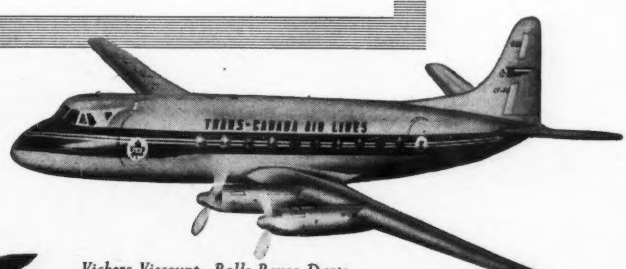

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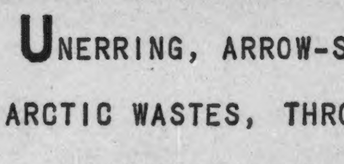

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Subscription—$4.00 a year. Single copy—50 cents.
Published monthly, except in July and August.
The Institute is not responsible for statements or opinions expressed in papers or discussions printed in its publications.
All communications should be addressed to The Secretary. Canadian Aeronautical Institute, 77 Metcalfe St., Ottawa 4, Ontario, Canada.

Authorized as second class mail, Post Office Department, Ottawa

Printed by The Runge Press Ltd., Ottawa, Ontario, Canada

ARROW

The Avro Arrow 1, with two Pratt & Whitney J-75 engines, was unveiled on the 4th October, on its transfer from final assembly to the flight test hangar. (See page 329).

EDITORIAL

THE RUSSIAN SATELLITE

It has been suggested that the launching of the Russian satellite on October 4th marked the beginning of a new age of space travel. Whether this was indeed the case is a question best answered in retrospect — several years from now. In the meantime, there is no doubt that the launching of the satellite was an event of the first importance to those scientific studies which relate to the high atmosphere and which figure prominently in the program of the International Geophysical Year.

A satellite of the kind recently launched provides much new information which is not restricted to observers in the satellite's country of origin. Some of this is common information, available equally to everyone who observes the satellite's behaviour. For example, measurements of the rate at which the velocity changes from day to day is a measure of the atmospheric density along the complete track. (A frictional loss of energy leads to a decrease in height and to an *increase* in velocity.) On the other hand, some of the information is local in character. The density of ionization in the ionosphere, its latitude gradient and its variation during magnetic storms and auroral displays, are best studied by means of radio measurements made at nearby stations as the satellite passes over the area of interest. It is for this reason that those countries over which the satellite passes are not only privileged but also are obligated, within the IGY framework of scientific cooperation, to make whatever observations are feasible.

In Canada, before October 4th, the early utilization of a satellite for upper atmospheric studies was not anticipated. The available information referred mainly to the American satellite which was scheduled to occupy an orbit passing well to the south of Canada. Suddenly, Canadian observers were presented with a satellite which passed over much of the Canadian territory. It was essential that a concentrated effort be made in order to obtain the observations which were necessary, first to establish the precise orbit and then to apply this information in atmospheric studies. Radio methods were used at the laboratories of the Defence Research Board and of the National Research Council, while optical methods were employed at the Dominion Observatory. Many other organizations assisted in the optical and radio observations. Even in the early stages, the freest possible exchange of information was maintained between the various participating groups and as soon as significant results were obtained they were passed to the IGY coordinating centre. The spontaneous nature of this cooperation speaks well for the maturity of Canadian science.

The tremendous popular appeal of the Earth's first artificial satellite may be due in part to its obvious similarity to the space vehicles of science fiction. However, the most immediate benefits for the aeronautical industry probably will be found in improved communication and navigation equipments. Such improvements may reasonably be expected to follow from the new knowledge concerning the Earth and its high atmosphere. Much has been written concerning the military, the political and even the moral implications of the new satellite. It is to be hoped that we do not overlook the importance, from the purely scientific point of view, of this latest method of investigating the planet on which we live.

Dr. P. A. Forsyth
Radio Physics Laboratory
Defence Research Board

AMENDMENT OF THE BYLAWS

WITHIN the next few weeks, the voting members of the Institute will be asked to vote on two Amendments to the Bylaws, one changing the name of one of the grades of membership and the other affecting the membership dues. The ballot papers will not contain a detailed explanation of the reasons underlying the proposed changes, but will refer to the following summary of the Council's thinking.

GRADES OF MEMBERSHIP

It is considered that the grade now known as "Technician" has been badly named. The name is often inappropriate and it has given rise to a good deal of misunderstanding in the past. Furthermore, the grade has always been intended for apprentices, trainees and others (except those qualifying as "Students") having less than 4 years' experience in technical work in aviation but this point has not been clear from the Bylaws, other than by inference from the definition of the higher grade of Technical Member – a Technical Member is defined as one having "at least four years" experience.

Consequently, it is proposed to change the name of the grade from "Technician" to "Junior Member" and to amend its definition to limit its membership to those of less than 4 years' experience – after the 4 years, the member must apply for advancement to the grade of Technical Member.

If this amendment is adopted, those now graded as "Technicians" will automatically be known as "Junior Members" from the effective date.

SCALE OF DUES

Background

When the Institute was formed, in 1954, it was in no position to offer any extensive services to members; these services had to be developed over the years. Initially, therefore, the annual dues were set at figures which were very low compared with those of other technical societies. For example, the dues for the grade of Member were set at $8 (including the non-deductible subscription to the Journal) whereas the dues for similar grades in the older societies ranged from $15 to $25.

Development

Due to the generous support of its Sustaining Members, the Royal Aeronautical Society, the Institute of the Aeronautical Sciences and the Engineering Institute of Canada, the Institute has been able to grow impressively during the last four years. Its financial position is very satisfactory, *for the present level of its activities.* But it must go on growing, expanding its services to members, developing Branch programmes across the country and so forth, and the Council considers that the Sustaining Members should not be expected to continue to carry so disproportionate a share of the financial load as they have done in the past; moreover, at this stage, the Institute should be able to stand on its own feet without any further grants from the sister societies. Consequently, if the Institute is to develop and to take its rightful place in the scheme of things, its individual members must assume a greater share of the financial responsibility. In brief, the dues must be increased.

Proposed New Scale of Dues

The proposed increase in the scale of dues is as follows:

For Fellows	$15 in place of $10
For Associate Fellows	$15 in place of $ 9
For Associates	$15 in place of $ 8
For Members	$10 in place of $ 8
For Technical Members	$ 8 in place of $ 7
For Junior Members	unchanged, at $ 5
For Students	unchanged, at $ 3

In addition, the special rates formerly enjoyed by members of the R.Ae.S., I.A.S. and E.I.C. will be abolished. Special rates, as follows, will apply in future only to members resident outside Canada and the U.S.A.

For Fellows	$10 in place of $ 5
For Associate Fellows	$10 in place of $ 5
For Associates	$10 in place of $ 4
For Members	$ 6 in place of $ 4
For Technical Members	$ 5 in place of $ 4
For Junior Members	unchanged, at $ 2
For Students	unchanged, at $ 2

The above figures, of course, include the subscription to the Journal, which will be sent automatically to all members unless they specifically state that they do not want it; even so, the subscription cannot be deducted from the dues.

Effective Date

It is proposed that, if the membership accepts this change and if it is approved by the Secretary of State, the new rates should come into effect on the 1st April, 1958.

Weight and Balance

The cost of everything is going up and the Council has been most reluctant to suggest yet another load on members' personal budgets. In the circumstances, however, after a careful study by the Finance Committee, the Council has decided that these increases in membership dues are necessary to the well-being of the Institute by ensuring a better balance of its financial structure.

It is hoped that members will recognize that the Institute must be weaned, to rely more on its individual members and proportionally less on its Sustaining Members for its future growth, and that they will accordingly support the Council in this Amendment.

TRENDS IN LUBRICATION†

by R. O. Campbell* and S. C. M. Ambler**

British American Oil Company Limited

FOREWORD

PRACTICALLY everyone directly connected with the aircraft industry is familiar with the great advances being made in the design and production of higher powered aviation gas turbine engines. Probably less familiar to the same people are the problems of the petroleum companies in connection with the development of oils to meet the lubrication requirements of these advanced types of engines. In an effort to present a resumé of some of the past developments, present problems and possible future developments in lubrication, the authors have based their text partially on their own past experience and have quoted many authorities on the old premise that —

"to quote one authority constitutes plagiarism,
to quote many authorities constitutes research."

FRICTION

Webster defines friction as the "resistance of one surface to the motion of another surface rubbing over it".

Generally, the tangential force F that accompanies rubbing is proportional to the normal force N pressing the surfaces together. This proportionality is called the coefficient of friction f and $f = F/N$. When there is no lubricant between the rubbing surfaces, the coefficient of friction f depends more on the characteristics of the materials in contact than on the area of contact, the speed of rubbing, or the roughness of the surfaces. However, this paper will be limited to lubricant characteristics and no further reference will be made to materials of construction.

Friction is related to the submicroscopic roughness of the rubbing surfaces. Surface roughness is measured by magnifying the movement of a fine tipped diamond over the surface. The Profilometer and the Brush Surface Analyzer are instruments in general use for surface roughness measurement. Even the smoothest "superfinished" surfaces have roughness peaks and valleys varying from 4 to 40 micro-inches. The friction force results from the lifting of surface irregularities over each other, the plastic welding and subsequent shearing off of the peaks, and the plowing of irregularities through the softer of the rubbing surface materials. Reduction of friction and resultant wear is best accomplished by providing a film of lubricant between the rubbing surfaces.

†Paper read at the Annual General Meeting of the C.A.I. in Ottawa on the 27th May 1957.
*Chief Chemist.
**National Supervisor, Industrial and Transportation.

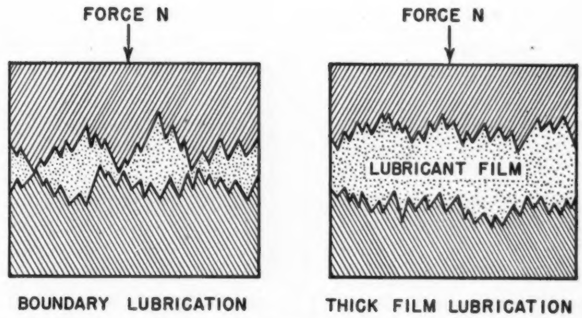

Figure 1

LUBRICATION

The lubrication of two rubbing surfaces with a liquid lubricant is generally accomplished under one of two conditions — "boundary" or "thick film", as illustrated in Figure 1.

Under boundary lubrication conditions, the interlocking surface irregularities are first welded and then sheared as rubbing takes place. Friction becomes the force required to shear the welded junctions. Friction, wear and increased temperatures are associated with boundary lubrication, but to a much lesser degree than when no lubricant is present.

Under thick film lubrication conditions, the rubbing surfaces are completely separated by the lubricant and, under ideal conditions, there is no shearing of metal and, consequently, no wear. In practice, however, there is a period of boundary lubrication during initial starting and stopping of motion and wear momentarily takes place. Also, foreign bodies, such as particles of iron, abrasive dust or other hard materials, contaminating the lubricant, may exceed in dimension the thickness of the oil film and cause scratches on the bearing surfaces. In the case of piston engines, the acidic nature of condensate water from piston ring blow-by gases can cause "corrosive wear" during periods of prolonged shut-down.

Under thick film lubrication conditions, metal shearing is replaced by the shearing of oil and, if the proper viscosity of oil is used, there will be less friction and heat evolved than with boundary lubrication conditions.

The ability to support a heavy load under thick film conditions is due to the velocity effect as the fluid lubricant is drawn through a wedge formed by two non-parallel surfaces. The velocity of the fluid at the stationary surface is zero and the velocity of the fluid

at the moving surface is equal to the velocity of the surface. The difference in fluid velocity between surfaces results in a pressure build-up which forces apart the surfaces, as illustrated in Figure 2. This figure illustrates a plain journal bearing under conditions of no motion, initial starting and normal motion. Bearing clearances and oil film thickness are exaggerated for the purpose of illustrating the principles involved.

VISCOSITY

Viscosity is the shear strength of a fluid. Viscosity can be defined in absolute units (centistokes) and can be accurately measured. It is viscosity, or resistance to shear, that causes a fluid lubricant to be pulled into a wedge by the moving surfaces of a bearing.

The energy required for the shearing of a lubricant is converted into heat and results in a power loss in the bearing. If the amount of heat developed by fluid shear is excessive, both the lubricant and the bearing metals will be adversely affected. If the viscosity of the fluid lubricant is too low, no protective wedge will be produced and bearing failure can result. If the viscosity of the fluid lubricant is too high, the temperature becomes excessive and bearing failure can result due to decomposition of the lubricant and/or failure of the bearing surfaces.

The selection of the proper viscosity of lubricant for a given bearing and set of operating conditions is necessary to obtain optimum operating conditions. By use of a lubricant circulating and cooling system, the lubricant becomes its own heat disposal medium in the cooling of the bearing system.

VISCOSITY INDEX

The change in viscosity of a lubricant due to temperature is expressed in terms of Viscosity Index (V.I.). A high V.I. lubricant does not change greatly with a change in temperature. A high V.I. lubricant is very desirable where operation is required over a wide range of temperatures. The present ASTM, D567-53 method of measuring V.I. has served the industry well over the past years. However, an improved method must be developed to properly define viscosity-temperature characteristics of recently developed petroleum and synthetic oils having V.I.'s higher than 150 by the present system.

PETROLEUM LUBRICANTS

Liquid lubricants refined from petroleum have almost quantitatively displaced earlier lubricants, such as animal and vegetable oils. The high performance quality of petroleum lubricating oils, their availability in almost unlimited quantities and their very low cost has made them the preferred lubricants for all but a very few specific applications. Constant research and process development by the petroleum industry has continually improved the performance quality of petroleum base lubricating oils.

Petroleum lubricating oils, while composed almost entirely of hydrogen and carbon, are among the most complicated of chemical substances. They are composed of thousands of different hydrocarbon molecules, differing in size and chemical configuration. Modern refining methods are based largely on methods of molecular sorting.

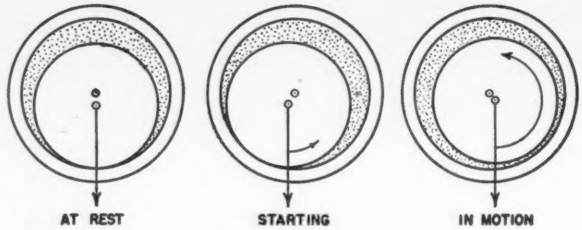

Figure 2
Journal bearing lubrication

Modern high vacuum distillation equipment sorts out the different naturally-occurring lubricating oil fractions from the crude petroleum, according to volatility, viscosity and molecular size.

Improved methods of dewaxing sort out and remove the naturally-occurring paraffin waxes from the lubricating oils, thereby improving their mobility and pumpability at low engine starting temperatures.

Modern solvent refining processes selectively sort out molecules of the aromatic type. It is desirable to remove the aromatic molecules because of their poor thermal and oxidation stability and because of their poor viscosity index characteristics. Lubricating oils processed by selective solvents have greatly improved thermal and oxidation stability. They have greatly improved viscosity indices and desirably improved volatility-viscosity characteristics.

The solvent refined lubricating oils are subsequently finished by contacting with catalytic clay or by hydrogenation. These finishing treatments control and stabilize colour and add further to thermal and oxidation stability.

By the processes of molecular sorting, the undesirable types of molecular structures have been progressively removed from the desirable types of molecular structures. In refining a typical Midcontinent or Alberta naturally-occurring lubricating oil distillate to produce a finished refined lubricating oil having a 95 V.I., as much as 55% or more of waxes and aromatic extracts must be removed, thereby leaving a yield of 45% or less of the high quality refined lubricating oil.

INCREASING OIL TEMPERATURES IN AUTOMOTIVE ENGINES

During the past thirty years, the power output of both gasoline and diesel automotive engines has been steadily increased without an increase in engine dimensions. In some cases, engine dimensions were decreased at the same time power output was increased. Increases in engine power were usually accomplished by raising compression ratios and engine speeds, along with the necessary changes in valves and intake systems to accommodate the increased volumes of required fuel and air.

These engine changes resulted in marked increases in crankcase oil, piston and bearing operating temperatures. They were usually made without increasing the volume of oil circulated and with little effort being made to reduce its operating temperature.

In the year 1926, average crankcase oil sump temperatures were approximately in the range of 130°F. For this reason, the Society of Automotive Engineers Crankcase Oil Classification adopted in that year used oil viscosity at 130°F as one reference point. Today it

is not uncommon to find oil sump temperatures in excess of 250°F during some conditions of engine operation.

It is axiomatic in hydrocarbon chemistry that the oxidation and decomposition susceptibility of a hydrocarbon oil doubles with each 18°F increase in temperature. From this axiom, it is evident that the influence of operating temperatures as an oil oxidation and decomposition accelerator has increased in severity to as much as 128 times higher than it was thirty-one years ago.

High speed automotive type diesel engines were first to develop ring-stick and varnish conditions due to high temperature operations. As speeds, loads and temperatures were increased, in order to adapt these engines to tractors and automotive uses, the ring-belt temperature was found to have a decided influence on the products of decomposition of the lubricating oil. In the elevated temperatures of the ring-belt, gummy deposits, whether from the chemical by-products of the combustion of fuel or from the decomposition of lubricating oil, function as binders to cement carbon and dust in the ring grooves and ultimately produce ring sticking.

LUBRICATING OIL ADDITIVES

Early in the 1930's, engineering personnel of the Caterpillar Tractor Company, with the assistance of oil company chemists, attacked the diesel ring sticking problem[1]. The most important information developed in this program was that the blending of lubricating oils with certain metallic-soap detergents produced compounded oils that would permit ring-free engine operation for many thousands of hours.

These detergent compounded oils pointed the way to improved engine performance and greatly reduced maintenance. Test results and field operating data definitely substantiated the increased life of rings and cylinder liners and longer uninterrupted service between shutdowns for the repair of engine reciprocating parts.

Another outcome of the Caterpillar ring sticking test program was the development of a single cylinder diesel test engine for the evaluation of ring sticking, which was to eventually become a qualifying test for oil detergency by the petroleum and automotive industries.

All hydrocarbons are subject to oxidation if contacted with air or oxygen at elevated temperatures for sufficiently long periods of time. Although certain chemical compounds, particularly sulphur compounds, were known to function as inhibitors of oxidation reactions when compounded with lubricating oils as early as 1870[2], they did not attain general usage until the late 1930's.

Higher automotive engine speeds and temperatures resulted in certain engine manufacturers changing from soft low melting point Babbit bearings to harder copper-lead bearings in the late 1930's. The new copper-lead bearings were susceptible to corrosion by acids from lubricating oil oxidation and acidic condensates from piston ring blow-by gases.

Oxidation and bearing corrosion inhibiting additives were the logical solutions to the problems and rapid development and usage of these products soon became accepted practice with refiners of lubricating oils.

By 1939, a number of oil companies were distributing additive type oils possessing the desirable characteristics of detergency, stability and ability to prevent alloy bearing corrosion. These oils were marketed as "Diesel Oils" to the diesel engine operators and as "Truck and Bus Oils" to the gasoline engine operators. In November, 1940, the late Dr. H. R. Wolf[3] suggested the term "Heavy Duty Oils" and this term has been used by the automotive and oil companies ever since.

Some of the chemical additive classifications used in the compounding of modern heavy duty oils are as follows:

(1) Pour point depressants
(2) Oxidation and corrosion inhibitors
(3) Detergents
(4) Viscosity index improvers
(5) Antifoam agents

AIRCRAFT PISTON ENGINES

According to Beal[4], the selection of lubricant for early aircraft engines was practically confined to one oil – castor oil. Following World War I, there was a complete shift from castor oil to improved quality petroleum oils.

Due to the inherent thermal stability of the higher viscosity oils used in piston aircraft engines, combined with good exchanger cooling and relatively high rates of oil consumption, lubrication with the best refined oils did not present many major problems. Even today, most commercial and military specifications for aircraft piston engine lubrication oils are based on the exclusive use of fractions derived from petroleum. Probably the great expense of operating full-scale engine tests and the fact that such tests by engine manufacturers were usually conducted in conjunction with tests to evaluate some factor or factors in engine design or materials, or both, prevented the aviation engine industry from developing standardized engine oil qualifying tests, such as were mutually developed and adopted by the automotive engine manufacturers and the petroleum refiners.

Only during the most recent years have chemical additive compounded oils appeared in piston engines in commercial aircraft operations. With the rapid transition from piston engines to gas turbine engines in both military and commercial aircraft, it is probable that very little further research will be carried out with regard to the utilization of additives in lubricating oils for piston aircraft engines.

AIRCRAFT GAS TURBINE ENGINE LUBRICANTS

In the early phases of operating aircraft gas turbines, there did not appear to be any serious problems connected with general and cold weather operations[5]. At first, gas turbine engines in the U.S. were lubricated with Specification MIL-O-6081 Oil, Grade 1010, with a pour point of –70°F. At the same comparative time, the British used a somewhat more viscous oil, since their permissible engine starting specification was –40°F, as against a U.S. specification of –65°F.

In these early turbine engines, bearing temperatures seldom went above 300°F and ram air coolers brought the bulk oil temperature down to 150-175°F. With such a low bulk oil temperature, the petroleum oil still possessed adequate viscosity for the lubrication of the roller bearings of the turbine shaft and the gears of the auxiliary drives.

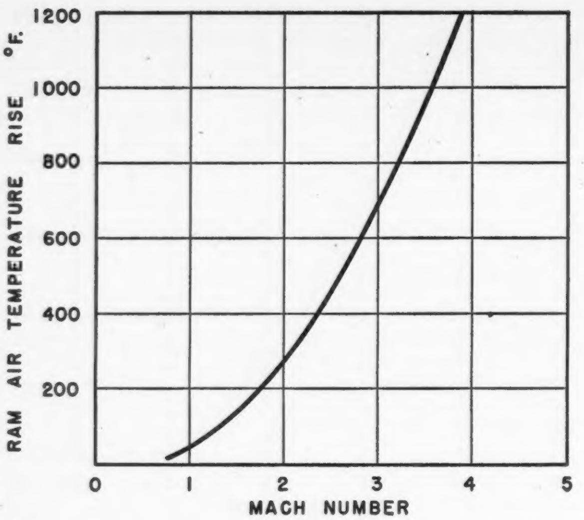

Figure 3

As new gas turbines were developed to enable planes to fly higher and faster, bulk oil temperatures increased to 250°F and turbine bearing temperatures increased to over 400°F, with soak-back temperatures in the order of 500°F[6]. By the year 1951, lubricant requirements became so exacting that petroleum oils could no longer satisfy both the low and high temperature operating conditions imposed by the newer aircraft turbine engines.

Actually, as early as 1946, sufficient data had been amassed to show that normal, petroleum-based lubricants were not very satisfactory for use in gas turbine aircraft engines. At this time, a great amount of experimentation was conducted on many viscous organic liquids, such as polyglycol ethers, phosphate esters, silicones and diesters[7]. Of all the organic liquids under development as gas turbine lubricants, the diesters, such as the adipates, azelates and sebacates, showed the best and most promising test results. From the very start, it was necessary to use chemical additives in the diester synthetic lubricants to impart further thermal and oxidation stability, gear load carrying ability and prevention of excessive foaming.

One of the first and most successful of the diester synthetic lubricants, introduced commercially in 1951, used di (2-ethyl-hexyl-sebacate) as the base oil, tricresyl phosphate as an extreme pressure gear additive, phenothiazene as an antioxidant, Acryloid as V.I. agent, and silicone as an antifoaming agent[8]. Engine testing data indicated that this synthetic lubricant offered superior load carrying ability, good temperature and viscosity stability and eliminated such turbine bearing coking difficulties as existed in the gas turbine engines in operation at that time. The new synthetic product had a vapour pressure of 0.1 mm of mercury at a bulk oil temperature of 300°F, as against 25.0 mm for Grade 1010 petroleum oil. Consequently, the loss of synthetic oil from evaporation was but a small fraction of that previously experienced with the petroleum oil.

Although the new synthetic oil cost over twelve times the cost of petroleum lubricant, there were economies to be gained in its use. It was on this early synthetic lubricant and other formulations, introduced in 1951, that U.S. Specification MIL-L-7808 was based. The British, still using a –40°F engine starting base temperature, brought out a somewhat more viscous synthetic lubricating oil during the year 1951.

Since 1951, aircraft gas turbines have been satisfactorily lubricated with the diester-plus additive types of synthetic oils. At the April, 1957, SAE National Aeronautical Meeting, Davidson and Way[9] stated—"Although MIL-L-7808 oils have done a good job and allowed us to operate gas turbines and fly aircraft, it might not have been possible to do so without performance sacrifices; further improvements in oil performance are presently desired." They summarized their current experience with MIL-L-7808 oils using ten operational aircraft, representing bombers, transports and interceptors, powered by turbojet and turboprop engines. They cited areas for necessary improvements in oil performance, namely, corrosion, oxidation and thermal stability, gear and bearing fatigue resistance, and load carrying ability.

One of the outstanding difficulties to be encountered in developing stable lubricants for future high speed aircraft is the ram air temperature rise/Mach number relationship shown in Figure 3. According to Davidson and Way[9], at Mach 2.3 the ram air temperature rise is in the neighbourhood of 400°F, which is approximately the bulk oil temperature level at which future engines will be operating. Therefore, it is obvious that, in the future, ram oil air coolers will be impracticable during high speed operation because they could conceivably act as "oil-heaters" rather than coolers.

Eventually, some other method of oil cooling will have to be devised if liquid lubrication of future gas turbines is to be retained. Some consideration has been given to evaporation cycle cooling with the coolant circulation being completely separated from the lubricant circulation. The separate coolant could be circulated through channels in the outer race of the roller bearings to effect heat transfer from the bearings.

Considerable experimental work has been conducted on bench test rigs to determine the feasibility of lubricating roller bearings with air-blown mists of solid lubricants. Johnson and Bisson[10] report successful tests using air-blown molybdenum disulphide and graphite to lubricate tool steel bearings in the temperature range of 500-1,000°F. They also experimentally operated a compressed air supported bearing. Their work is of an exploratory nature and they state that considerable research is required on both bearings and lubricants under simulated or actual operating conditions as a final check on these materials. An interesting diagram from their report is shown in Figure 4, which illustrates the temperature-limited ranges of the lubricants evaluated in their tests. Nemeth and Anderson[11] have also reported on their work on solid lubricants in roller bearings.

The main problem facing the petroleum companies, at the present time, is the development of improved natural or synthetic oil bases and better supplementary chemical additives. When the need for synthetic oils first became apparent, the petroleum industry turned to fluids that had previously been developed for hydraulic oils, instrument oils and chronometer oils. Presently, many other types of oils and chemical additives are under development.

Improved methods of refining, or "molecular sorting", such as new solvent treating processes or thermal diffusion processes, may produce natural petroleum base oils of much higher thermal and oxidation stability. Since the diester oils are predominantly composed of carbon and hydrogen, it is only logical that petroleum be the raw material for the synthesis of improved future lubricants.

To hasten the development of new improved lubricants, close cooperation between engine manufacturers and the petroleum refiners is required. At present, most petroleum refiners have to do their early development and testing of prototype lubricants on bench equipment, such as the Ryder Gear and Lubricant Tester, the Pratt & Whitney Panel Coking Test Unit and other such items of simulated testing. The transition from bench to engine tests must be made a cooperative effort, as only the engine manufacturer possesses the prototype engines requiring the improved lubricants.

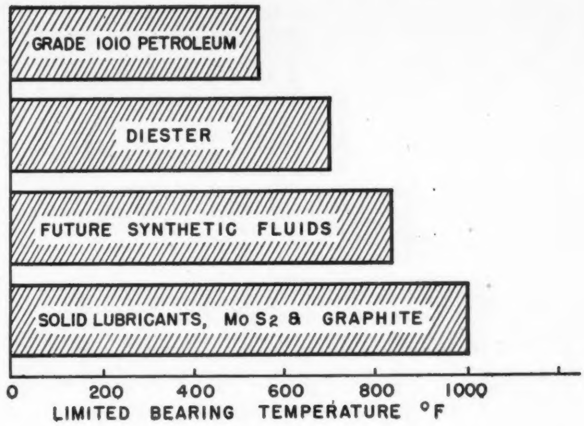

Figure 4
NACA bench tests

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A METHOD OF RECORDING AND MEASURING LIMITS OF VISIBILITY FROM COCKPITS OF CIVIL AIRCRAFT†

by P. J. Foley,* K. B. Jackson and D. O. Blake*****

Defence Research Medical Laboratories and University of Toronto

DEFENCE Research Medical Laboratories were asked by the Department of Transport to devise a method of measuring and recording limits of visibility from aircraft cockpits. The technique to be developed was to be such that measurements could be made speedily and reliably by relatively untrained personnel, and that records for specific aircraft could be readily compared with standard requirements.

METHOD

To simplify the task the following limitations were imposed.

(a) It was decided that changes in visibility limits resulting from gross bodily movements be ignored. Pilots, while scanning, can look forward and effectively "look around" an obstruction. However, one cannot assume that this will be done continually and it appeared more realistic to confine measurements to the situation where only the head rotates. Any deviation from this procedure would give greater visibility limits and consequently more safety.

(b) It was assumed that the pilot has a cyclopean eye and that measurements should be made from the position of this eye in the cockpit. This assumption is not so drastic as may at first appear. The average interpupillary distance is 60 mm, so that the lateral displacement involved in taking a mean position between the two eyes is 30 mm for each eye. The error involved is relatively so small as to be negligible. The savings in terms of the technique are considerable. It is realized, however, that a monocular obstruction to vision may not be a binocular one. If it is essential in certain cases that the binocular obstruction be measured, this can be done by displacing the camera 1¼ inches to the left and right of the cyclopean eye position and superimposing the resulting pictures.

(c) It was assumed that the head rotates about a vertical axis through the eye. Although this point is approximately 8 cms forward of the true pivot of the head, it can be demonstrated that no errors are introduced.

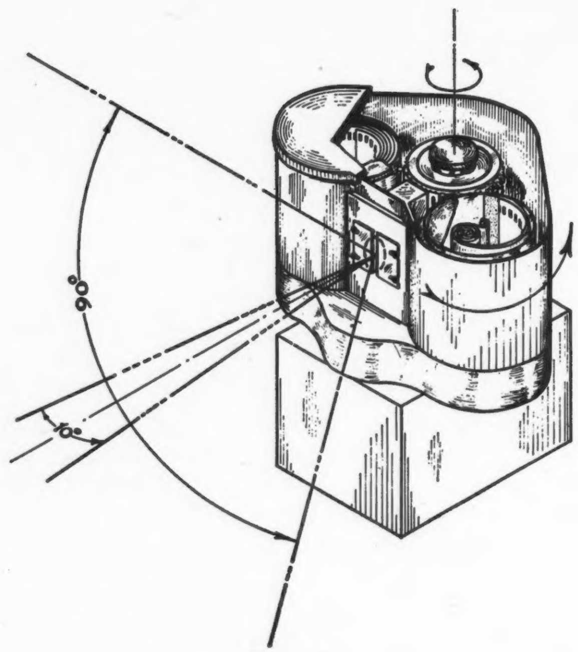

Figure 1
The camera

Having regard to the purpose of the study and these assumptions, it was decided that some form of photographic technique would be most suitable. Accordingly, the camera shown in Figure 1 was designed and constructed.

This camera takes 70 mm perforated film, which is loaded into the right hand cassette. From this cassette the film is led forward of the centre drum, the perforations engaging the teeth on the drum, into the take-up cassette on the left.

A ¼ hp, 1 rpm Bodine spur gear synchronous motor supplies the power. When this motor is operated through a gear system, the camera rotates about a vertical axis

†Received 30th July, 1957. This paper is Defence Research Medical Laboratories Project No. 204, DRML Report No. 204-1. P.C.C. No. D77-94-20-33, H.R. No. 146.

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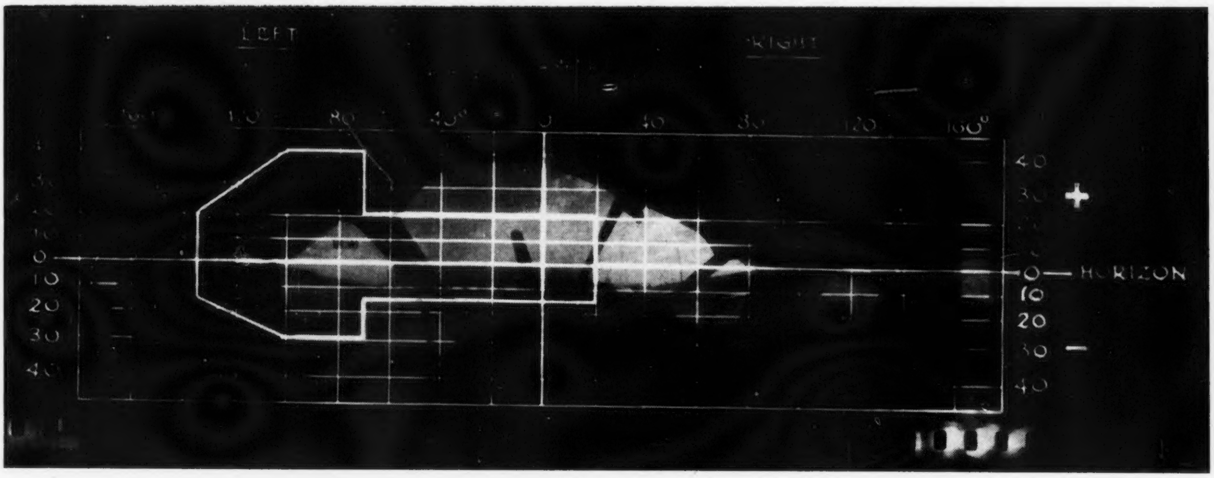

Figure 2
Sample recording made with the camera (De Havilland Beaver)

through the "lens" from the left to right at a speed of 2 rpm. The centre drum is also driven through the gear system and rotates from left to right at the same speed.

Instead of a conventional wide angle lens, a pinhole, .004 inch in diameter, was placed at a focal length of 1 inch from the plane of the film. The decision to use a pinhole was made after a series of trials had shown that, with modern fast emulsions, the pinhole diameter needed for the short focal length used gave manageable exposure times. The exposure time with the present camera, using Tri-X film, is of the order of 0.8 second. The pinhole mounting is baffled to give 90° coverage in the vertical plane and 10° coverage in the horizontal plane. The narrow vertical slit is used to reduce the distortion due to the film being on a cylinder. The resulting panorama is equivalent to a mosaic of the centre strips of a series of photographs around the horizon.

To mount the camera, a monopod was designed which can be fitted to the pilot's seat in any aircraft cockpit. Fairly easy adjustments in three dimensions permit the pinhole to be located at the position of the pilot's hypothetical cyclopean eye.

The operation of the camera is a straight forward matter. It is mounted on the monopod and located at the correct position in the cockpit. A reference mark is placed on the windscreen to indicate the position of the horizon when the plane is in normal flight and to establish the correct position of the grid overlay. The motor is then switched on and the camera allowed to rotate twice, to ensure that the front of the cockpit will be imaged on the centre portion of the subsequent film strip.

RECORDING AND MEASUREMENT

Samples of the photographic recordings are shown in Figure 2.

On these recordings can be seen the grid overlay which was constructed to facilitate angular measurements on the photographs. Angles on the grid are spaced as follows. Horizontally $360° = 2\pi R$, where R is the focal length of the "lens" and the radius of the film cylinder. Vertically $Y = R \tan V$, where Y is the distance from the horizon and V is the vertical angle.

Since one of the purposes of the study was to ensure that records of the visibility limits of specific aircraft could be easily and reliably compared with the required visibility limits, the standards laid down by DOT (CAM 4b. 351(a)) were plotted on the grid overlay so that they, too, appear on the photographs. Thus it is possible to tell at a glance if a specific aircraft meets DOT requirements and it is also possible to make angular measurements from the same photograph, if and when required.

NOISE—SOME IMPLICATIONS FOR AVIATION†

by Dr. K. K. Neely*

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SUMMARY

Noise has become one of the important problems in aviation. Its effects on hearing, voice communications, man's ability to perform certain tasks, are becoming more and more pronounced.

Criteria and regulations for the protection of personnel from high intensity noise have to be initiated and implemented. Similarly criteria and procedures have to be formulated and used to minimize the decrease in efficiency with which man can communicate and work in high intensity noise areas.

Suggestions are outlined that will aid the airport operators to attenuate and control high intensity noise which may result in an increase in the efficiency of airport operations.

INTRODUCTION

NOISE, any unwanted sound, has become one of the important problems associated with modern aviation. The intensity of noise generated by aircraft has increased and this increase in noise has been accompanied by an increase in the number of people exposed. In this paper I should like to discuss briefly some of the noise problems associated with the operation of airports.

Exposure to noise may cause: (1) a reduction in hearing acuity; (2) interference with the transmission and reception of information by voice communications; (3) changes in the efficiency with which man can perform certain tasks; (4) mechanical or pathological damage to the body; (5) arouse feelings of fear, apprehension, annoyance or dissatisfaction; and (6) antagonistic community response to the presence of airports and aircraft and, under certain conditions, to the people who work at the airport and who man the aircraft. Directly or indirectly, these effects may cause a change in operational procedures and plans or they may mean the unsuccessful completion of a flight.

People primarily exposed to and affected by high intensity noise are those who operate and service the aircraft. Non-operational personnel at airports, such as administrative personnel and airline personnel, and airline passengers using the airport are affected by noise, usually psychologically. People living in the immediate vicinity of airports who may not be directly concerned with aviation are also affected.

The control and attenuation of noise can be accomplished by one or more of the following methods: (1) providing personnel exposed to high intensity noise with equipment to protect their hearing mechanism, head, or whole body; (2) using procedures which remove the source of noise from the personnel; (3) providing sound attenuation structures at the source so that exposure to noise will not be hazardous.

High intensity noise presents many complex problems for airport management. Airport designers, community planners, local, provincial and federal officials, as well as the otologist, audiologist, voice communication engineer, maintenance engineer and aircraft engine manufacturers, must all play their part in the reduction and control of high intensity noise.

SOUND

The magnitude of sound is measured in terms of sound pressure (dynes per square centimetre) or in sound energy (watts per square centimetre) (see Table 1). The range of sound pressures to which man is exposed is very large. For example, from silence to painful sound is an increase in sound pressure of from 0.0002 dyne per square centimetre to 632 dynes per square centimetre, which is a linear scale of 3,160,000 units.

In order to deal with this broad range of pressures, a logarithmic system has been adopted which will yield a linear scale of 13 units. In this system, where logarithms are taken to the base 10, the unit is known as a *bel* and is the logarithmic ratio of two sound powers. One bel indicates 10 times the power; two bels indicate 100 times the power; three bels indicate 1,000 times the power etc.

However, sound measuring instruments give indications of sound pressure levels. Since sound pressure varies as the square root of power, one bel increase in power is the square root of 10 (3.16) times the pressure; two bels indicate the square root of a 100 times the pressure; and three bels indicate the square root of 1,000 (31.6) times the pressure. To avoid inconvenient fractional values and since the bel is a large unit, the *decibel* (db), one-tenth of a bel, is used.

As indicated in Table 1 and Figure 1, the overall noise level at the pilot's position in the S-55, Viscount or Neptune aircraft, operating at cruising speed, varies between 95 and 110 db[1, 2]. In the Comet 3, at this position, the overall noise level is approximately 80 db. There are many types of noise, each having a particular spectrum or distribution of sound energy. The noise generated by piston engined aircraft usually has its sound energy concentrated below 600 cycles per second, while jet

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†Paper read at the Annual General Meeting of the C.A.I. in Ottawa on the 28th May 1957. This paper is DRML Sonics Memorandum 82.

*Chief, Sonics Section.

TABLE 1
POWER AND SOUND PRESSURE LEVELS

Acoustic Power at Point Source		Characteristics of Sound at 30 Feet			
Power (Watts)	Power Level (DB RE 10^{-13} Watts)	Sound Pressure Level (DB RE 0.0002 Dyne/CM²)	Power (Watts/CM²)	Pressure (Dynes/CM²)	
100,000	180	140	10^{-2}		
				1,000	50 HP Victory Siren (100′)
10,000	170	130	10^{-3}		
1,000	160	120	10^{-4}		
				100	
					–Engine Room Submarine (Full Speed)
100	150	110	10^{-5}		S55 (Pilot Position)
10	140	100	10^{-6}		–Viscount (Pilot Position)
				10	–Neptune (Pilot Position)
1	130	90	10^{-7}		
					–Subway Car (Toronto)
0.1	120	80	10^{-8}		
				1	–Comet 3 (Pilot Position)
0.01	110	70	10^{-9}		
0.001	100	60	10^{-10}		
					–Conversational Speech (3′)
				.1	
0.0001	90	50	10^{-11}		
					Private Office
0.00001	80	40	10^{-12}		
				.01	
0.000001	70	30	10^{-13}		
					–Broadcast Studio (Speech)
0.0000001	60	20	10^{-14}		
				.001	
0.000,000,01	50	10	10^{-15}		
0.000,000,001	40	0	10^{-16}	.0002	

aircraft generate noise whose sound energy is distributed over a wider range of frequencies.

The overall noise levels outside the Comet 1A ranged from 112 to 128 db measured at a distance of 100 ft from the aircraft (see Table 2). Outside the T-33 aircraft, the overall noise levels varied from 100 to 117 db, with overall noise levels of 106 to 118 db being measured outside the F-86E aircraft[3]. The noise generated outside the F2H3 varied from 107 to 128 db. The Viscount, a turboprop aircraft, generated noise whose overall level varied from 90 to 112 db, while the noise generated by the Neptune, a pistoned engine aircraft, varied in overall level from 102 to 110 db. The B-47, powered with six J-47 engines, generated noise whose overall noise level varied from 117 to 137, depending on the angle at which the noise was measured.

The usual distribution of sound energy generated by jet aircraft is indicated in Figure 2. Regardless of power, the area of greatest sound pressure is between 120-150°[4]. The sound energy distribution of the noise generated by various jet aircraft on the ground is indicated in Figure 3.

As an example of the levels of noise that can be expected in the near future, the overall noise level measured at a position 125 ft directly underneath the

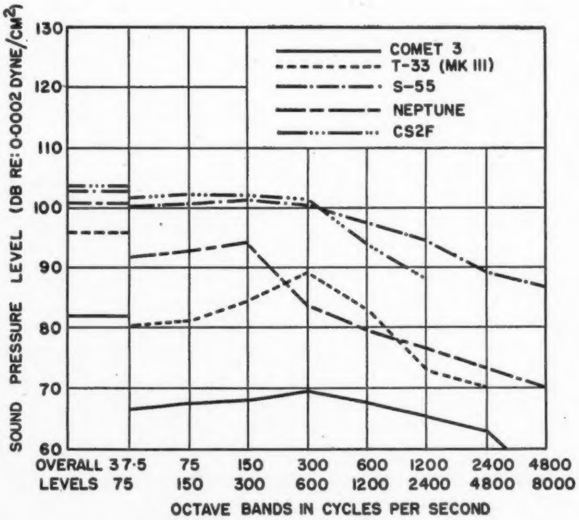


Figure 1
Aircraft noise spectra measured under flight conditions at the pilot's position

TABLE 2
OVERALL NOISE LEVELS, VARIOUS AIRCRAFT MEASURED AT A DISTANCE OF 100FT UNDER STATIC CONDITIONS
(DB RE: 0.0002 Dyne/CM²)

Aircraft Type	Angle			
	0	45°	90°	135°
Comet (Jet)	124	128	112	128
T-33 (Jet)	100	107		117
F-86E (Jet)		106		118
F2H3 (Jet)	107	109	114	128
Viscount (Turbo)	112	101	95	90
Neptune (Piston)	110	109	102	106

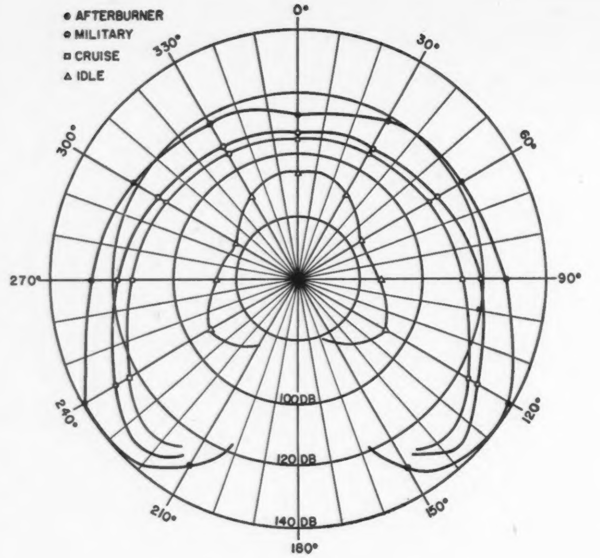


Figure 2
Typical overall noise level distribution about jet aircraft under static conditions

Comet 1, shortly after takeoff, was 123 db. Under similar measuring conditions, the Constellation produced an overall noise level of 110 db, the DC-4 produced 104 db, and the DC-3 produced 101 db. The Comet produced a noise level 13 db greater than that for a Constellation – a considerable increase in noise level. It is indicated that the Boeing 707, using a new silencing device, with its four J-57 engines, will generate overall noise levels comparable to those of the DC-7, which are approximately 124-128 db measured at a distance of 100 ft at an angle of 135°. The DC-8 aircraft should generate overall noise levels similar to those of the Boeing 707.

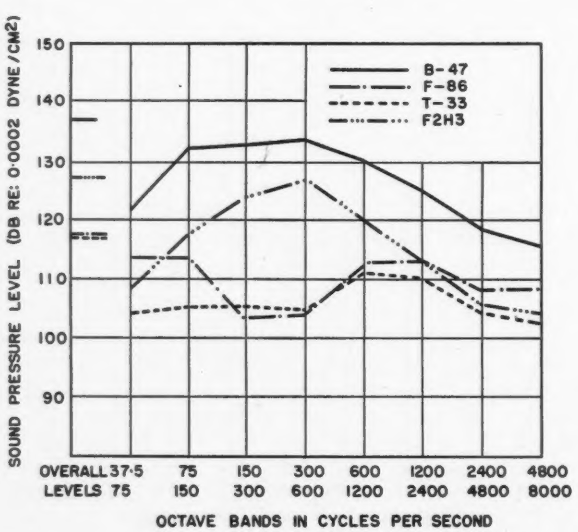


Figure 3
Aircraft noise spectra measured on the ground at a distance of 100 ft and an angle of 135°

TABLE 3
NOISE PROTECTION CRITERIA

Noise Sound Pressure Level (Decibels RE: 0.0002 Dyne per CM²)	Type	Exposure Time	Type of Protection
85–100	Continuous Jet or Piston-Engine	Over 4 Hours	Optimum Ear Plugs or Ear Muffs
100–130	Continuous Jet or Piston-Engine	Any	Optimum Ear Plugs or Ear Muffs
130–150	Continuous Jet or Piston-Engine	Any	Optimum Ear Plugs and Ear Muffs
150–	Continuous Jet or Piston-Engine	No Exposure Permitted	

HEARING

For many years, noise was accepted as a concomitant of progress. Only a few years ago, noise whose overall level exceeded 120 db was the exception rather than the rule. Today, overall noise levels of 140-150 db are becoming the rule rather than the exception.

The threshold of pain, which occurs at approximately 130 db for most individuals, was used, until a few years ago, as an index of whether a noise was harmful or not. Research has indicated, however, that this threshold is approximately 35-45 db higher than the threshold for damage to the hearing mechanism produced by long term exposure to noise. Losses of hearing acuity may, however, be caused by factors other than noise. A certain number of people will develop hearing losses as a result of aging or of disease or other pathological factors which are not related to exposure to noise. It is most difficult to distinguish between hearing losses due to non-noise factors and those occasioned by exposure to noise. There are a number of data, both clinical and experimental, which indicate that long time exposure to jet or piston engine noise, whose overall level exceeds 85 db, may cause both temporary and permanent hearing loss. The amount of damage that will be suffered will be a function of (1) overall sound pressure level of the noise, (2) spectrum of the noise, (3) duration of exposure, (4) length of time between exposures and (5) the state of the person's organ of hearing.

The Sonics Section, Defence Research Medical Laboratories, have prepared for use by the Royal Canadian Air Force criteria for hazardous exposure to noise generated by jet or piston engines (see Table 3)[5]. These criteria are similar to those recently proposed for use in the United States Air Force and which are contained in USAF Regulation 160-3. The wearing of ear plugs in areas where the overall noise level is below 100 db will not only provide protection to the hearing mechanism but will make possible an increase in listener intelligibility of approximately 5-8%.

Results of sound attenuation tests indicate that the MSA Standard (V-51R Type) or the MSA 2A insert type ear plugs provide the most effective noise attenuation for this type of ear protector (see Figure 4). The "Safe-T-Ear Muff" developed by Dr. G. J. Thiessen at

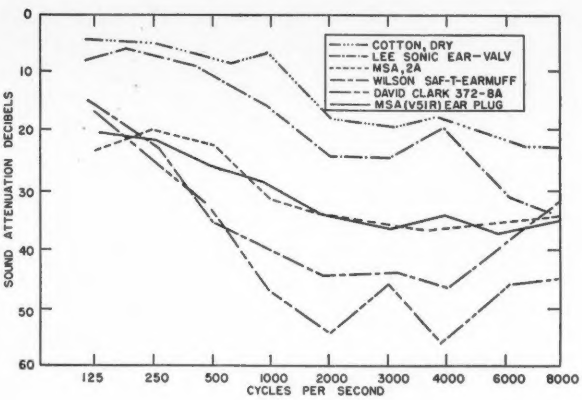


Figure 4
Sound attenuation—ear protectors

the National Research Council, Ottawa, or the David Clark Ear Muffs, provide the most effective noise attenuation of that type of ear protectors[6, 7]. The NRC Ear Muff is more acceptable since it is more comfortable. Cotton and the Lee Sonic Ear-Valv provide little sound attenuation. Experimental evidence indicates that an optimum insert ear plug together with an optimum ear muff will provide approximately 5-8 db more sound attenuation than either ear plug or ear muff alone. The most efficient protection *available at the present time*, optimum ear plug plus optimum ear muff, will provide protection to the hearing mechanism of personnel exposed to noise with overall levels *not in excess of 150 db*. It should be noted that the present ear protectors which reduce the intensity of airborne vibrations through the external ear canal have almost reached their maximum effectiveness. The level of bone-conducted sound, reaching the cochlea through the head, neck, chest and other parts of the body, is reduced approximately 40-50 db, depending upon frequency, from the level of air conducted sound through the external ear canal.

Exposure to noise whose overall level exceeds 140-145 db may cause non-auditory effects, such as nausea, nastagmus, temporary blindness, vertigo, incoordination and unconsciousness. These symptoms are usually accompanied by a compelling desire on the part of the exposed person to remove himself from the noise environment. Exposure to noise of 160 db will probably rupture a person's ear drums. In summary, it can be stated that the best evidence available today indicates that the human tolerance level for high intensity noise is 150 db, provided the person is wearing the most efficient ear protectors. Work to date indicates that ultrasonic frequencies (above 20,000 cps) do not *at the present time* present a hazard.

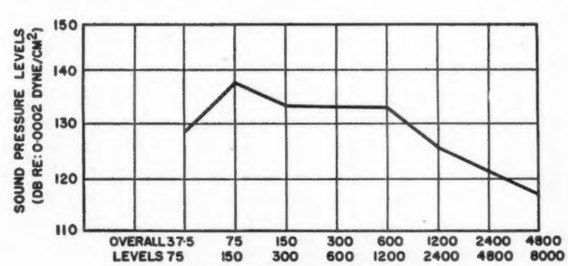
Above 145-150 db, the problem becomes one of protecting the whole body. Investigations by the Clothing Research and Sonics Sections, DRML, indicate that clothing materials will provide approximately 6-8 db of sound attenuation at the low frequencies. This amount of attenuation is not sufficient. Other means of protection will have to be found. Consideration should be given to the use of sound-proofed, power-operated capsules or small reinforced concrete bunkers for the protection of personnel who work in high intensity noise environments. Adequate tests for man's susceptibility to noise have yet to be devised and the immediate and accumulative effects of long time exposure are not yet fully understood.

VOICE COMMUNICATIONS

Man with "normal" hearing can hear from 20 to approximately 18,000 cps. However, a frequency range of from 300 to 6,000 cps is required for intelligible speech, particularly under adverse noise conditions. A large proportion of civilian and military information flow is accomplished by the use of voice communication. Requirements for an adequate voice communication system include efficient acoustical noise-free environments for both the speaker and the listener. While the efficiency of the voice communication system is a function of intelligibility of the speech, listener familiarity with the speech and the speech transmission characteristics of the audio equipment, it is also a function of the signal-to-noise ratio. It should also be noted that an efficient voice communication system is of no use if the information desired or necessary for the successful completion of an operation is not transmitted.

There are several ways of evaluating the masking or interrupting effects of noise on a voice communication system (see Figure 5). One of the methods involves the use of a measure called speech interference level (SIL). To obtain the SIL the noise must first be analyzed in terms of octave-bands. Then the sound pressure levels, in decibels, for the three octave bands (600-1200; 1200-1400; 2400-4800 cps) are arithmetically averaged. The resulting figure, in decibels, is the SIL for that particular noise. While this measurement can only be used in certain well defined types of noise environments, it does provide an indication of the extent of the noise masking on voice communications. As indicated in Figure 5, if the SIL is 65, speech will be intelligible if the distance between the speaker and the listener does not exceed 1 ft and the speaker uses a "normal" voice level. Likewise, if the SIL is 49 db, the distance between the speaker and listener should not exceed 6 ft if the speech intelligibility is to be adequate. The use of a telephone is adequate if the SIL does not exceed 60 db; at 75 db the use of a

DISTANCE (ft) FROM LISTENER	0·5	1·0	2·0	3·0	4·0	5·0	6·0	12·0	24·0
SPEECH INTERFERENCE LEVEL	71	65	59	55	53	51	49	43	37



NOISE SPECTRA, B-47 AIRCRAFT, MEASURED AT 100 FEET AT AN ANGLE OF 150°

$$\text{SIL (DECIBELS)} = \text{SPL IN OCTAVE BANDS } \frac{600-1200:1200-2400:2400-4800}{3}$$

$$= \frac{134+125+121}{3}$$

$$= 126$$

Figure 5
Speech interference levels for normal speaking voice

telephone is impossible. Voice communications would be useless in a noise environment similar to that generated by the B-47 at a distance of 100 ft, at an angle of 150°. In fact, adequate communication between two people would not be possible even at a distance of a mile if the two people were more than 2½ ft apart. Voice communication efficiency may also be reduced by an increase in overall noise levels caused by (1) number of men employed in the area, (2) number of messages transmitted or received, (3) high gain settings of intercom equipment, (4) lack of training in the correct "listening" procedures, (5) inefficient placement of intercommunication equipment and (6) incorrect type or improper use of intercommunication equipment. Recently we assisted in the design of consoles and voice communication systems for the new RCAF control towers. This work was reported in the JOURNAL for January, 1957. Included in the recommendations was one which would locate the control towers remote from sources of high intensity noise, such as maintenance areas, taxi-strips and takeoff areas. It was also recommended that noise attenuation materials be used in the tower as an aid in providing an adequate acoustical environment.

The efficiency of communication can be improved by training in proper speech intelligibility techniques and by the use of standardized, intelligible voice messages.

Recent studies have indicated that the addition of visual cues to auditory cues under certain conditions raise the intelligibility of received speech by approximately 20%[8]. This indicates that television, speech or lip-reading and hand signals would be of some assistance in increasing the efficiency of communications for personnel working in high intensity noise environments. The most efficient voice communication equipment that we have today is not adequate for use in jet aircraft type noise exceeding 120-125 db.

Unfortunately we do not have tests available that will adequately assess the ability of personnel, who have various types and degrees of hearing losses, to perceive and understand speech or other auditory signals in noise. Procedures for ensuring adequate communication in high intensity noise have yet to be worked out.

MAN'S ACTIVITIES

Both field and laboratory studies have been conducted to ascertain the effects of noise on man's ability to perform certain tasks. While many of these have studied the action of the hearing mechanism, some have been concerned with man's ability to perform certain everyday tasks. Most have used overall noise levels that have been comparatively low, i.e. below 120 db, and comparatively short durations of exposure, i.e. up to 4-5 hours. Results of these studies on personnel engaged in mental or motor tasks not involving voice communications have been inconclusive or have indicated no significant change in performance.

Little is known about the effect on man's ability to perform certain tasks following exposure to noise, for either short or long periods of time, whose overall level exceeds 120 db.

AIRPORTS

Let us consider the noise problems that are associated with the operation of airports and which will become acute in the near future. The overall noise levels must be reduced so that maintenance and operational personnel will not suffer hearing losses; communications will not be impaired; administration personnel will carry out their work without reduced efficiency; passengers will not become irritated; and people living in neighbouring communities will not become antagonistic toward the airport and its personnel.

One of the most efficient methods of minimizing the problem of noise at airports would be to reduce it at its source. Ground installations, which are expensive, can be built that will afford a measure of noise attenuation during engine-testing operations. However, the attenuation of noise at the source in airborne aircraft is relatively unsuccessful to date. A reduction of 4 to 8 db in noise is all that has been achieved without a significant loss in thrust.

There is agreement that new jet transport aircraft will produce greater noise levels than those now being generated by such aircraft as the Super Constellations, North Stars, Viscounts, Convairs and DC-7's. In addition, since jet aircraft differ from pistoned engine aircraft in that their takeoffs and landings are done at a much flatter angle, larger areas will be exposed. As the volume of aircraft traffic increases, the duration and frequency of exposures will increase.

What can be done? There are many things that can be done.

(1) Long range planning should help ensure adequate land being available for airports. Long runways mean that large jet aircraft have a greater period of time to become airborne and thus a reduction in noise can be achieved since the aircraft can take off at reduced power. If sufficient land is available, then the airport can be isolated from neighbouring communities. This type of planning demands the whole-hearted cooperation of federal, provincial and local governments.

(2) Noise level limitations should be formulated. The airlines and engine manufacturers should be informed that if these regulations are not met then aircraft of that type will be forbidden the use of the airport. It is very important that these noise regulations be given consideration by the engine manufacturers at the design stage of new aircraft engines. The aircraft manufacturers have to face the noise problem as they have the problems of speed, efficiency and safety.

(3) Airports should be planned so that administration offices and passenger reception and departure areas will be situated at least 2½ miles from the engine test areas, runways and first-line maintenance areas. This will aid in ensuring that adequate voice communications can be maintained and the "comfort" of passengers will not be interfered with.

(4) Control towers should be located remote from high intensity noise areas. They should also be acoustically treated to provide optimum voice communication conditions.

(5) The layout of airports should include the use of hangars and other structures as barriers between the noise sources, such as engine test-beds and surrounding communities. High parapet walls, built parallel to the runways, might be another method of reducing the noise.

(6) Another problem confronting airport management is that of blast waves generated by aircraft flying at supersonic speeds. These blast waves may cause damage to buildings and other aircraft. Administration and passenger reception and departure buildings could all be located underground. Aircraft could be towed from the landing strips to the passenger reception and departure areas if it becomes necessary.

(7) A committee, composed of airport and airline officials as well as noise specialists, should be responsible for the consideration and solution of the problems of noise arising from airport maintenance, ground aircraft traffic and airborne traffic procedures. This committee should be responsible for initiating noise control procedures and for taking action against any offenders. Management should assign specific responsibility for noise and its control.

(8) A good public relations program is essential. Keeping the public informed of the importance of aviation and of the measures that are being taken to minimize the hazards and irritation occasioned by noise is a very important job.

(9) Regulations should be formulated and implemented as regards angle of climb and descent, power settings and flight patterns that will help ensure that the least number of people will be exposed to noise for the least amount of time.

(10) Adequate hearing conservation programs for the protection of all personnel exposed to high intensity noise are a necessity.

(11) Adequate communication systems have to be developed *and used* by all personnel who have to work in high intensity noise environments.

(12) At airports where military aircraft are operated, the degree of procedural change that can be achieved is more limited than at airports where only civilian aircraft are operating. Full power takeoffs at all times of the day or night are essential for the efficient carrying through of air defence requirements. However, in these situations there is still much that can be done, especially by initiating and carrying through efficient public information programs.

(13) Another problem that will have to be faced is that of helicopter noise. We can expect helicopter service to become an important link between small centres and downtown areas of large centres and airports. Helicopters in use today generate overall noise levels somewhat comparable to those generated by DC-3 aircraft. However, the passenger helicopters are expected to have much higher noise levels. The solutions to the problems of noise demand that a coordinated attack be made by government, airport and airline officials, as well as the engine manufacturers and consultants, in the fields of noise, hearing, communication and architecture. Long range planning of airports, ground and air traffic control procedures and of flight patterns are very important. Legislation is needed for their implementation and enforcement. These problems can be satisfactorily handled by hard work and cooperation between the various people and organizations concerned.

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AIRCRAFT GAS TURBINE ICE PREVENTION— THE DESIGN AND DEVELOPMENT OF HOT AIR SURFACE HEATED SYSTEMS†

by C. K. Rush* and D. Quan**

National Research Council and Orenda Engines Limited

SUMMARY

The problem of protecting an aircraft gas turbine engine from the hazards of icing is presented from a designer's point of view. The basic objective is a system having minimum weight and performance penalties together with maximum duration of protection and reliability. Consideration of the various available protective methods points to the hot air surface heated system as a satisfactory compromise, provided a control system is used to prevent the waste of hot air. The design of such a system is then considered and it is pointed out that the many assumptions which are made lead to the necessity of development tests so that the design may be proved and refined. The advantages of the use of icing tunnels for component and assembly testing and development are discussed.

INTRODUCTION

THE occurrence of icing on aircraft gas turbines presents the most critical icing problem on modern aircraft and complete failure can occur within a matter of seconds. Whereas the early engines with centrifugal compressors had a considerable measure of self-protection, the present day engines with axial flow compressors experience serious difficulties due to their critical aerodynamic performance and the large surface areas exposed to icing. Axial compressors suffer a rapid loss in efficiency due to ice formation on the guide vanes, stator blades and rotor blades. Choking of the air flow is a serious effect and leads to increased fuel flow to maintain engine speed, which quickly leads to excessive tail-pipe temperatures, and shift of the compressor working line causes the engine to behave abnormally. Ice formations on the nose bullet and support struts, while not causing trouble as quickly as those on the blades, must also be prevented, for they eventually cause the same difficulties and may also grow large enough to present a structural hazard if they break loose. Damage to an engine from ingested foreign particles, such as chunks of ice, gravel, bolts or broken compressor blades, seems to be a random phenomenon, where neither the largest pieces nor the greatest quantity at any one encounter will necessarily wreck the engine. Sometimes a very small piece will cause total engine failure. An engine designer is, therefore, left with no doubt that if his engine is to encounter icing conditions it must be protected. This paper summarizes one approach to the design and development of a suitable ice prevention system.

METEOROLOGICAL DESIGN CONDITIONS

The first step in the design of an ice prevention system is the selection of the meteorological design conditions. Sometimes these are determined by military or civil airworthiness requirements specified by a number of licensing and approving authorities. These requirements vary widely and some are much easier to meet than others. To avoid unsatisfactory operational experience, even though the system meets the requirement of a particular specification, the engine manufacturer should make his engine to meet relatively severe conditions. Fraser, in Meteorological Design Requirements for Icing Protection Systems[1], proposes such requirements and a method of application. Two groups of parameters are used: a severity group which includes ambient air temperature, liquid water content, droplet size and pressure altitude; and a distribution group which includes geographical and seasonal occurrence, and the lateral and vertical extent and variation of the severity conditions.

The distribution parameters are an important factor in the initial selection of the kind of protective system to be used. For example, because the vertical extent of icing is limited to altitudes less than 40,000 ft and is of rare occurrence from 20,000 to 40,000 ft, a high altitude bomber would require protection for a small portion of its airborne time whereas a maritime reconnaissance aircraft might require continuous protection. A light weight system with relatively high fuel consumption would suit the first case whereas a heavier system with low fuel consumption would suit the latter. When the kind of protection to be used has been selected, the distribution parameters are mainly of operational significance and affect the design of the system in that they define the 'amount' of icing protection required. That is, they dictate how much extra fuel or other load is required to maintain protection throughout the icing conditions.

The severity requirements are based on three experimentally determined relations:

(i) a relation between maximum water content and temperature,

†Paper read at the Annual General Meeting of the C.A.I. in Ottawa on the 28th May, 1957.
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(ii) a relation between volume median droplet size and water content together with the use of an arbitrary droplet spectrum,

(iii) a relation between maximum average water content and the horizontal extent of icing.

These relations are then used to derive the basic meteorological design conditions, as given in Figures 1 to 3.

Figure 1 shows the relationship between water content and the ambient air temperature for several horizontal extents of icing.

Figure 2 shows the maximum total catch to be expected over a given extent of icing, for various temperatures for a catch efficiency of 100%. The expression of the catch in inches is based on the assumption of a specific density of ice of 0.8. For protective systems which are sensitive to water content and are properly controlled, the 'amount' of protection required is proportional to the total catch at a given temperature.

Figure 3 shows the relationship between water content and temperature of Figure 1, but with the temperature expressed as a pressure altitude in a standard atmosphere.

It is also necessary to know something of droplet size. The accepted measure of droplet size in icing technology is the volume median diameter, which is the droplet diameter in a spectrum which marks the division of the total volume of water into equal parts, one containing droplets less than, the other greater than, the median volume diameter. Reference 1 proposes a typical distribution as follows:

Percentage of total water content	3	8	20	30	20	10	5	4
Droplet diameter ratio to MVD	0.27	0.55	0.83	1.10	1.39	1.67	1.95	2.22

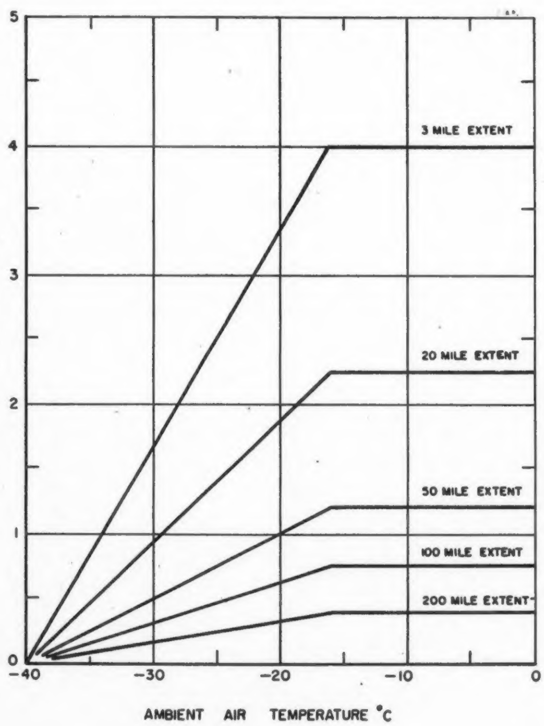

Figure 1

Severity requirement—water content vs temperature

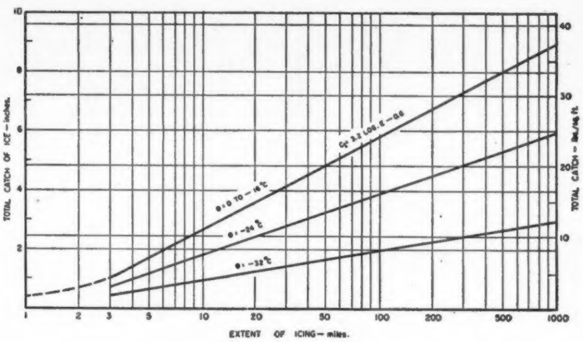

Figure 2

Distribution requirements—total catch of ice vs extent of icing

and gives a relationship between the median volume diameter (MVD) and water content, as shown in Figure 4.

CHOICE OF SYSTEMS

As previously indicated, the choice of an icing protection system may be influenced by the kind of aircraft in which the engine is to be installed. However, engine manufacturers cannot foresee all the applications for any engine at the system design stage and some flexibility in the protective system is required so that it may reasonably meet different operational needs without undue penalties.

Two general methods of protecting engines are in common use: thermal, surface heated systems and fluid, freezing point depressant systems. Surface heated systems secure heat either from hot gas flowing in double-skinned components or from electric resistance heating in the form of heater pads or direct resistance heating by passing current through the part itself, a stator blade for example. Hot gas may be obtained by bleeding air from the engine compressor. Its temperature may be

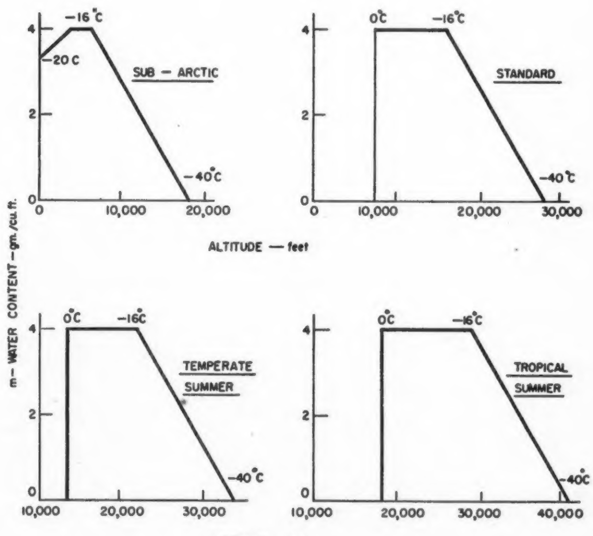

Figure 3

Severity requirements—liquid water content vs altitude for 0 to 3 miles extent (based on ICAN standard atmosphere)

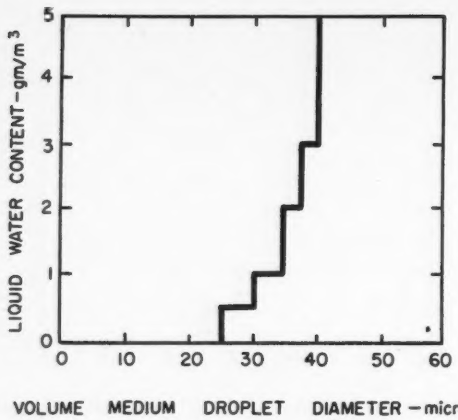

Figure 4
Droplet size vs water content

increased by the direct introduction of combustion gases from the engine or by the use of intermediate heat exchangers exchanging heat from the hot combustion gases to the cooler compressor air. However, augmenting the temperature in this way leads to a more complex and heavier system than the use of compressor bleed air directly. The mixing of combustion gas and compressor bleed air also has the disadvantage of contaminating the compressor air. The direct compressor bleed system is characterized by its relative simplicity, low fixed weight, moderate fuel consumption, unlimited endurance as long as the engine is running, minimum maintenance potential and its dependence on engine speed for adequate performance. Electric resistance systems are characterized by their high fixed weight, low rate of fuel consumption, independence of engine speed and a moderate maintenance potential.

Fluid systems, which use alcohol in one form or another as the freezing point depressing agent, are characterized by moderate installed weight, limited endurance and moderate maintenance potential. Two incidental disadvantages of alcohol are the poisoning of the compressor air so that it cannot be used for cabin pressurization and the reluctance of aircraft operators to keep a supply of anti-icing alcohol and to see that the system is properly serviced.

These then are the main factors which must be weighed in selecting the system to be used. For particular missions, performance studies can be made to clarify the relative merits of the various systems. In this study, the engine is considered to be for use in a high performance aircraft which is expected to operate most of the time at speeds and altitudes which eliminate the icing hazard but which must be protected during takeoff, approach and landing. Under these conditions, the hot air surface heated system has an outstanding advantage in its low initial weight. This advantage, combined with a favourable outlook for reliability and low maintenance time, places it in a favoured position for this application. The performance penalty at high engine speeds associated with direct bleed systems with on-off control can be minimized by using an air flow control system modulated by the actual requirement.

Surface heated anti-icing protection may be achieved in two ways: all water impinging on the surface can be evaporated (dry anti-icing), or the water can be maintained in a liquid state over the wetted surface (wet anti-icing). Dry anti-icing applications are usually confined to large aircraft components, such as the wings and engine cowlings. In general, heat requirements for such a system to meet the meteorological design conditions previously discussed will be found to be prohibitively high for the intake components of a gas turbine. These may be designed for wet anti-icing for the critical conditions of

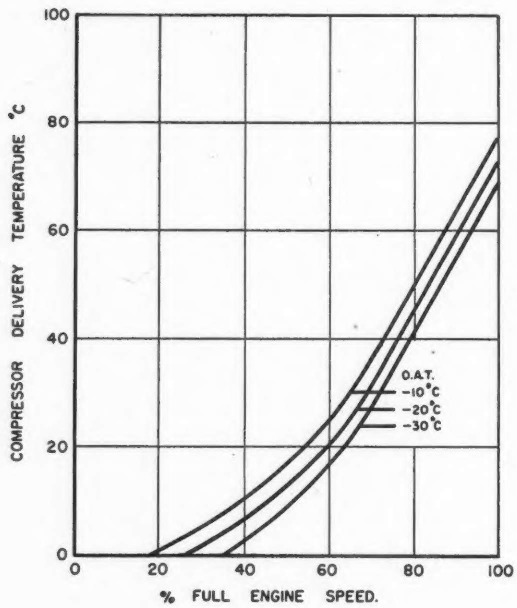

Figure 5
Typical compressor delivery temperatures vs engine speed (for varying ambient temperature)

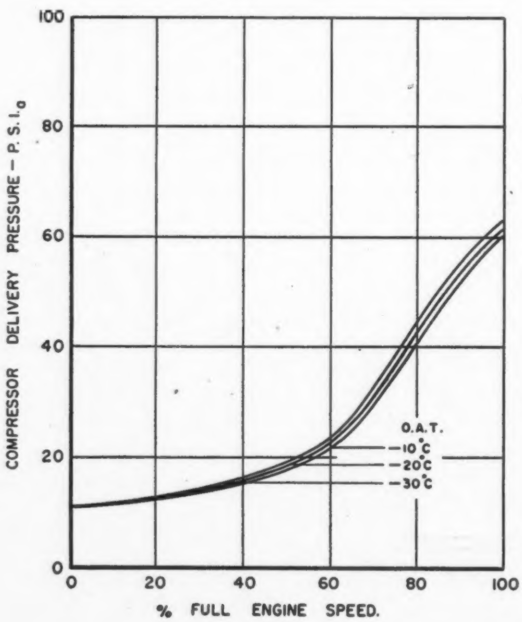

Figure 6
Typical compressor delivery pressure vs engine speed (for varying ambient temperature)

low engine speed and high water content. Of course, dry anti-icing may be achieved for other operating conditions.

SOME DESIGN CONSIDERATIONS

The components of a gas turbine which need to be protected in a wet anti-icing system include the nose bullet, the support struts, the guide vanes and the rotor and stator blades, from the first stage to the location in the compressor where there is self protection due to kinetic and compressive temperature rises.

The temperature and pressure of the supply air will depend on engine speed, outside air temperature, altitude and aircraft speed. For the present study, the static sea level case will be examined so that supply air temperature will depend on engine speed and outside air temperature, in the manner illustrated in Figure 5. The supply pressure for the static sea level case will also depend on engine speed, in the manner of Figure 6.

The effect of increasing pressure and temperature as engine speed increases results in a marked reduction in flow requirement at the higher engine speeds. If no provision is provided for flow throttling then much air is wasted, as illustrated in Figure 7. Control of the flow may best be obtained by installing a modulating valve in the heating air supply pipe and making it vary the flow to maintain a desired surface temperature so that heating air in excess of that actually required is not used.

The manner in which the hot air is piped from the compressor to the various parts to be protected requires careful consideration. Components may be linked in series or parallel connections. Generally, a series system is most efficient but pressure drop limitations may require at least some components to be connected in parallel. A system where the guide vanes, nose bullet and support struts are connected in series is illustrated in Figure 8.

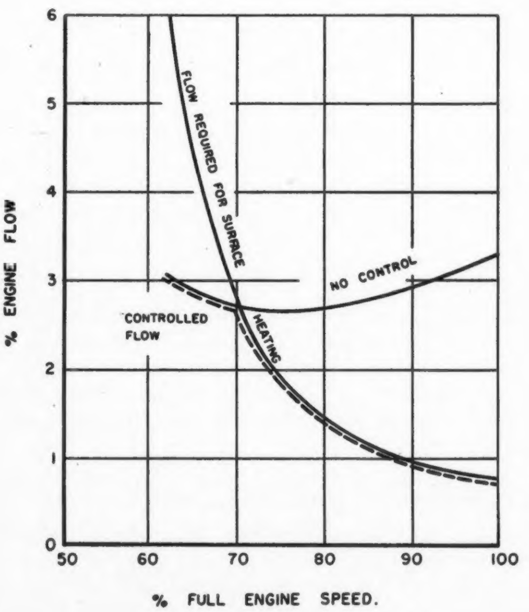

Figure 7
Comparison of typical compressor bleed flow required for surface heated anti-icing system with and without a control system

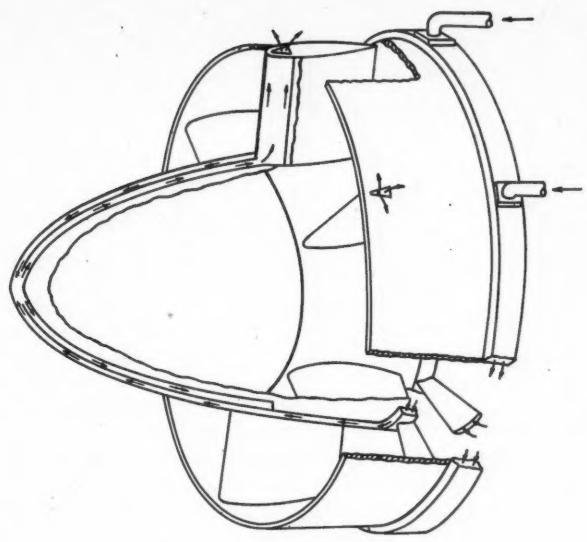

Figure 8
Inlet with series connected components

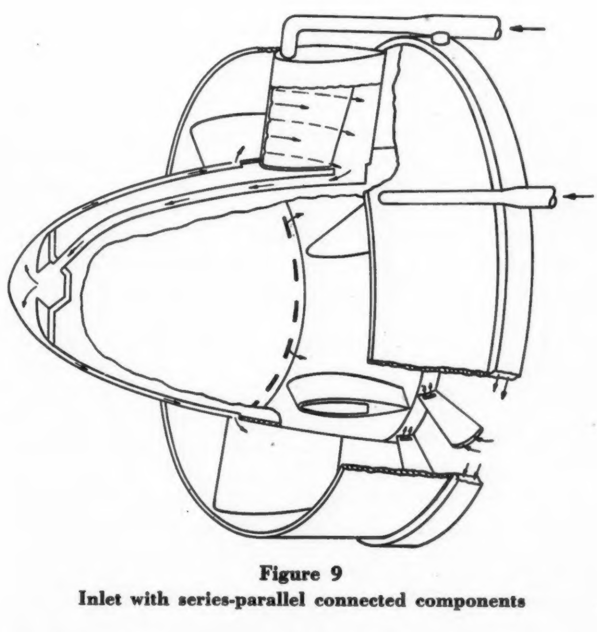

Figure 9
Inlet with series-parallel connected components

The layout should provide the hottest air to the components having the highest heat transfer rates. In the case of the system shown in Figure 8, the air goes first to the guide vanes which have by far the greatest heat transfer rate, then to the nose bullet and, last of all, the support struts. A compromise has been made in this case because the support struts actually have a higher heat transfer rate than the nose bullet but the piping arrangement illustrated allows the spent heating air to be exhausted outside the engine intake.

A parallel-series arrangement is illustrated in Figure 9, where the guide vanes are paralleled with the support struts and nose bullet. Such a system has an advantage in permitting the maximum quantity of heat to be transferred to the guide vanes because all of the available

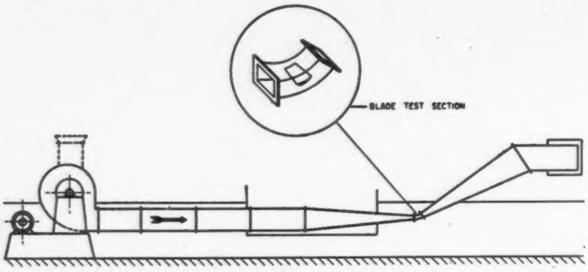

Figure 10
Blower tunnel set up for blade tests

pressure may be expended within this component which is usually the most difficult to protect.

After the system layout is tentatively selected, the heating air pressure and temperature for each component can be estimated so that the individual components can be designed. An iteration process is then required to obtain agreement between the estimated heating air conditions at each station and the actual calculations.

DESIGN METHOD

The determination of the rate at which heating air must be supplied to a surface to maintain it ice-free involves two heat transfer processes: an external transfer of heat to enable the surface to be kept free of ice and an internal transfer of heat from the heating air to the heated surface. The external transfer of heat is calculated by assuming a surface temperature somewhat greater than the freezing point. The analytical methods for calculating this were first developed by J. K. Hardy. Once the surface temperature is established, the internal heat transfer process can also be dealt with analytically. Both these methods are outlined in Reference 2.

Basically, in the external process there are six heat quantities involved: heat losses due to convection, evaporation, and water heating, heat gains due to kinetic heating of the water droplets and kinetic and viscous heating from the ambient air passing over the surface. The net deficiency in this heat quantity to maintain the surface at the desired temperature must be supplied from the heating air. For the internal process, the designer can vary the geometry of the heating air passages within the limitations imposed by the allowable pressure drops. Some of the variables at his disposal are the spacing between skins, gas paths and positioning of fins. To avoid too complicated a design, some surfaces may be overprotected to ensure adequate protection for all heated areas. Great care must be taken to avoid cold areas where ice may build up due to runback from the adequately heated areas.

Due to the complicated shapes that must be dealt with in an engine inlet, such as the twisted blades and the stubby support struts, even a careful and sophisticated study may not result in the optimum design for each component. This uncertainty together with others, such as the weight rate of water impingement, distribution of intercepted water and the external heat transfer coefficient, makes it extremely desirable that components be tested in icing conditions before the design of the whole assembly is finalized.

COMPONENT TESTING

Component testing can be carried out advantageously in an icing tunnel. Each component in turn can be set up in the tunnel and supplied with heated air at the desired temperature and pressure while it is tested over the desired range of meteorological conditions. Tests are best conducted with conditions simulating those at various engine speeds. Air flows for satisfactory protection may then be determined as a function of engine speed. In addition to determining air flow requirements, the shortcomings of the various components with respect to evenness of heating, area protected and air leakage are readily detected. The mode of failure may be studied without endangering an engine and heat transfer effectiveness for each component may be determined. The information thus gained will aid in assessing the merits or performance of each component and in carrying out any redesign. A major advantage of component testing is that redesigning or modification, at this stage, is relatively inexpensive and does not require excessive manufacturing time. For blade tests, it may be necessary to design special tunnels or to modify the working section of an existing tunnel, as shown in Figure 10. To proceed with icing tunnel tests, tables of engine operating conditions, similar to the following, are required for each set of meteorological conditions.

TABLE 1

Meteorological Conditions		ambient temperature $-10°C$ water content 1.5 gms/M^3					
Engine Speed	%	100	90	77	64	51	38
Tunnel Velocity	ft/sec	400	310	210	140	100	70
Max. pressure available at component entry	psi_a	50	50	50	35	25	15
Heating air temp. at component entry	°C	250	190	120	80	40	10

It should be noted that the independent variables in this table are the ambient temperature, water content and engine speed. A set of tunnel tests corresponding to these conditions is made, starting with the highest engine speed and working down until icing of the component occurs. The results from several such sets of tests are then combined, as illustrated in Figure 11, to establish the minimum engine speed at which the component can be adequately protected. These curves for the various components of a system may be compared to reveal any wide discrepancies. The required flows at each condition are also measured for comparison with the analytical flows to show whether any component must be redesigned or modified.

ICING TUNNEL ASSEMBLY EVALUATION

After the components have been satisfactorily developed, the prototype assembly may be designed. Although it is recognized that compromises are necessary to design the complete assembly so that fabrication is possible using proven manufacturing techniques, nevertheless, good judgement should be exercised so that unsatisfactory component performance is avoided. After

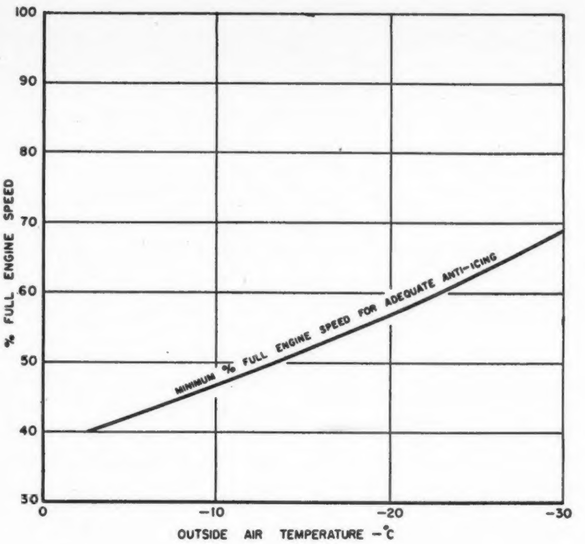

Figure 11
Typical performance of a hot air surface heated anti-icing system

assembly, the prototype should be given an air flow test to establish the pressure distribution and air consumption. This will make apparent any gross deficiencies, such as blocked air passages, unbalanced flow and serious air leakages.

The next step in the development should be carried out in an icing tunnel (Figure 12). This is the first time all the components are evaluated as a system and the effect of actual water droplet distribution, leakages, piping pressure and temperature losses, actual heating air distribution, end effects and manufacturing variations amongst similar components are exhibited.

The NRC 4½ ft icing wind tunnel is limited to speeds less than about 300 ft/sec so that the complete range of engine speeds cannot be investigated. Fortunately, for systems dependent upon engine bleed air for heating, the critical engine speeds are, for the most part, within the operating range of the tunnel. The matter of most interest at the high engine speeds is the operation of the flow control valves which modulate the flow of heating air to the actual requirement. These are functional tests and can be carried out without exact simulation.

Some of the main advantages of using a refrigerated icing tunnel for icing tests on an engine inlet, other than its very important advantage of year-round utility, are listed herewith:

(1) The psychological pressure of icing an engine with unpredictable consequences is avoided.

(2) Ice can be shed from an engine inlet in an icing tunnel without the possibility of engine damage.

(3) Time is gained because the system can be developed before development engines can be spared for anti-icing.

(4) Tests can be made under accurate and readily controlled conditions for extended periods of time without the difficulty of servicing and operating a slave engine.

(5) The operating costs of an icing tunnel are very much lower than those of an engine.

Upon completion of the icing tunnel tests, the development should have proceeded to the state where initial test bed runs may be carried out with confidence and a minimum of delay.

TEST BED EVALUATION

Tunnel testing shortens the time and reduces the cost of development of an anti-icing system, but some problems cannot be resolved by tunnel testing alone. With the actual engine, there may be differences from the simulated engine conditions which probably were derived from theoretical engine design performance data. There are also some effects, such as the aerodynamic performance, handling characteristics and ice shedding and ingestion, which can only be determined with a real engine. In particular, random ice shedding from the blades can cause unbalance and vibration. It has been reported that some engines are caused to flame-out from ingesting this randomly shed ice. The complete operating envelope of the engine should be explored for these effects because the amount of random shedding varies with engine speed and ambient temperature as a result of the variation in centrifugal force exerted on the collected ice and the adhesive strength of the ice.

In so far as the anti-icing characteristics of the protection system are concerned, the work done on the assembly tests in the icing wind tunnel will enable abbreviation of the test bed running to the previously established critical engine operating conditions, as illustrated in Figure 11. At this stage, if the previous development has been correctly carried out, these tests should be confirmative and should establish the limits of protection accurately.

FLIGHT TESTING

Flight tests to determine the performance of an anti-icing system are akin to those to determine the aerodynamic performance in flight of an aircraft, in that they are of little value unless they can be subjected to analytical treatment and reduced to a generalized form which is applicable to conditions other than those under which the tests were actually made. Particularly in the

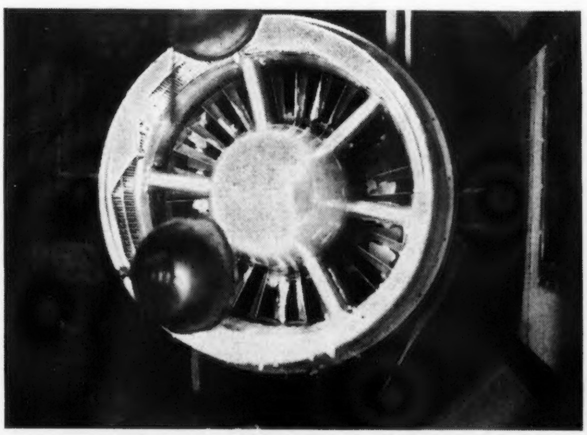

Figure 12
Inlet assembly in large icing tunnel

case of icing trials, it is quite impracticable to cover or obtain the range of conditions necessary for sound empirical data. In so far as gas turbine inlets are concerned, there are two groups of tests which may be performed. The first group consists of functioning tests to establish the correct design, manufacture and assembly of the system without reference to its behaviour in icing. Once again, it is pointed out that a proper program of icing tunnel and ground tests can do much to keep this part of the flight program to a minimum. The second group of tests concerns the performance of the system in icing. This is an exceedingly difficult phase, as has been pointed out by Fraser[1, 3]. It is highly desirable to keep flight trials to a minimum but they cannot be ignored because it is in flight that the kinetic and dynamic effects of forward speed need to be assessed. For a system with automatic metering controls, such as the hot air system that has been proposed, it may be necessary to make some preliminary flight trials to adjust the control to give optimum performance. Thereafter, the tests will consist of measurements of the flow of hot air and of the corresponding meteorological conditions, together with general observations of the anti-icing behaviour at various speeds and altitudes. At this stage, the information obtained during the assembly tests in the icing wind tunnel and during ground tests becomes indispensable in interpreting the results. It should be possible to extrapolate from the results of a few icing encounters, of any severity, to obtain the ultimate performance of the system by the methods of Reference 3.

CONCLUDING REMARKS

(1) The meteorological design conditions[1] which have been used as a basis for this report have no official status. They are generally regarded as being severe and ice protection systems designed to meet them should be wholly adequate. As pointed out, it is necessary to carefully analyze the operational role of the engine so that overdesign is avoided. Special emphasis should be placed on the engine speeds during icing encounters when considering compressor bleed systems.

(2) In a general way, it has been shown that a hot-air surface heated anti-icing system is preferred for gas turbines. Its outstanding disadvantage can be overcome by the use of an automatic metering control feeding only sufficient heating air to match the requirement.

(3) The method of developing gas turbine icing protection systems which has been presented should greatly reduce the overall time for the design-development cycle. In particular, by utilizing icing wind tunnels to the maximum extent, it is possible to avoid the misfortune of discovering a major deficiency during the limited icing season for ground test bed running and having to lose a year's time before the fault can be rectified and tested. This possible saving in time is in addition to that gained by being able to develop the system before an engine is available.

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ANNUAL GENERAL MEETING

The Annual General Meeting of the Institute

will be held in the

KING EDWARD HOTEL

TORONTO

on the

26th and 27th May, 1958

The Programme, which is now being prepared, will include Sessions on

Engineering Administration, Production Engineering, Design and Application of Computers, Ground Support Equipment, STOL and VTOL

as well as the annual Business Meeting.

This meeting affords an opportunity for the presentation of papers by members of the C.A.I. The Council is most anxious to encourage Canadian papers and hopes that any member wishing to contribute to any of the above-mentioned Sessions will submit a summary of his paper for consideration. Such summaries must be in the hands of the Secretary by the 31st December 1957.

C.A.I. LOG

SECRETARY'S LETTER

It is an unfortunate habit of ours that we hold most of our Institute meetings towards the end of the month. This makes it impossible for me to report on them, or even to comment on them in the Secretary's Letter, in the following issue of the Journal.

I.A.S./C.A.I. MEETING AND FOREIGN OBJECTS SYMPOSIUM

As we go to press, all I can say about the I.A.S./C.A.I. Meeting, held on the 21st-22nd October, and the Symposium on Foreign Objects in Aircraft etc., which took place on the 24th October, is that both turned out very well. With the help of the I.A.S., we cannot go far wrong in our Joint Meetings but I was particularly pleased with the Symposium, which was something of a new venture for us and which, I believe, achieved useful results. Full reports on both meetings will be given next month.

I.R.E. CANADIAN CONVENTION

There seems to be nowhere else in the C.A.I. Log to make mention of this bit of news and I think that it ought to be mentioned somewhere. Our Past President and our President have successively been on the Advisory Committee of the big 1957 IRE Canadian Convention held in Toronto on the 16th-18th October and our Vice-President, Mr. Britton, with Mrs. Britton sat at the Head Table at the Convention Banquet on October 17th.

I hope that many of our members were able to attend this important meeting, since the activities of the IRE are likely to have an increasing influence on aeronautical affairs.

NEW HEADQUARTERS

Things have a way of getting worse before they get better. On my return from my visit to England in mid-September, I was confronted with the usual problems associated with the start of a new season, the preparations for the I.A.S./C.A.I. Meeting and, to cap it all, a move to a new office. The plan is that an Assistant Secretary should be appointed, to carry some of the load of running this Headquarters and to enable me to get away occasionally to visit our Branches. But there was no room to put him in our old office and so, as a first step, we have moved to rather larger accommodation in the same building. Our new room number is 801 and I hope that members visiting Ottawa will take the opportunity to come and see their new Headquarters.

(It may be a little while before we can change our letterhead stationery. Our existing letterhead bears the old room number, 607. Anyone writing to us should either use the new number, 801, or omit the room number altogether.)

C.A.A.R.C.

In the first issue of the Journal, in April 1955, we reported on a visit by Commonwealth Advisory Aeronautical Research Council coordinators in High and Low Speed Aerodynamics and Low Temperature Operations. Now, two and a half years later, we had the pleasure of seeing some of them again. The Council met in Canada towards the end of September and the Ottawa Branch took advantage of their presence in Ottawa early in October to entertain them at a special Branch meeting. The meeting will be reported upon later by the Branch Secretary, but I mention it here because, in holding this meeting, the Branch was, in effect, representing the whole Institute in extending hospitality to these eminent Commonwealth visitors.

CHRISTMAS CARDS

I would draw attention to the C.A.I. Christmas cards which will be made available this year. The scale of prices is given in the Notice on page 330. The cards bear the C.A.I. Crest in full colour and are really rather pleasing I think; unfortunately they are not ready yet, as we go to press with this issue, so we cannot include a picture to show you what they look like.

THE ARROW

On the 4th October, I was privileged to be present at the unveiling of the Avro Arrow. Of course, I met a great many of my old friends at Malton, some of whom, I regret to say, are not yet members of the C.A.I.!

The fact that the unveiling coincided with the launching of Sputnik detracted nothing from the importance of the occasion. Here was a very impressive supersonic aeroplane produced by the Canadian aircraft industry. As it emerged, I could not help thinking that we had come a long way technically since the Lancasters rolled out of that same door.

SPUTNIK

The following exchange of correspondence took place after the launching of the Russian artificial satellite on the 4th October, 1957.

7th October, 1957

His Excellency The Ambassador of the Union of Soviet Socialist Republics,
The Embassy of the Union of Soviet Socialist Republics,
Ottawa, Ontario

Your Excellency,

On behalf of the Council and Members of the Canadian Aeronautical Institute, I would ask you to convey our sincere congratulations to the scientists and engineers responsible for the launching of the first artificial earth satellite.

We recognize the many technical difficulties which have been overcome and we wish to express our admiration of this great achievement.

H. C. LUTTMAN
Secretary

October 14, 1957

Mr. H. C. Luttman,
Secretary,
Canadian Aeronautical Institute,
607 Commonwealth Bldg.,
77 Metcalfe St.,
Ottawa 4, Ont.

Dear Mr. Luttman,

I thank you very much for expressing on behalf of the Council and Members of the Canadian Aeronautical Institute your sincere congratulations in connection with the launching of the first artificial earth satellite.

I have already had your message sent to our scientists and engineers responsible for the launching and they will undoubtedly greatly appreciate it.

Yours sincerely,
D. CHUVAHIN
Ambassador of the USSR to Canada

MID-SEASON MEETING

HOTEL VANCOUVER

VANCOUVER

27th and 28th February, 1958

BRANCHES

NEWS

Vancouver

September Meeting

Reported by A. F. Coutts

On Monday, September 15th, the first meeting of the program year 1957-58 was held at the new Aero Club quarters, with 40 members and guests present. Since this was the first meeting of the season, the business session consisted of a brief rundown of the proposed program for the coming season.

Our speakers, Mr. A. L. Bingham, Performance Engineer, C.P.A.L., Mr. R. McCormick, Factory Representative, Canadian Pratt & Whitney, and Capt. C. Lamb, Pilot, C.P.A.L., were introduced by the Chairman, Mr. H. H. Ollis. The subject of the evening was accident investigation.

Mr. Bingham spoke of the factors considered in determining from physical evidence the manner in which the aircraft broke up and whether the break-up had commenced before impact or at the time of impact, and the angle, attitude and control positions at the instant of impact.

Mr. McCormick described the procedure used to determine engine performance, power settings and clues to possible power plant malfunction as a contributing factor to the accident.

Capt. Lamb covered the problem of determining whether an error had been committed by the flight crew and if what appeared to be an error was not, in fact, a situation brought on by other influences prior to the time of the accident.

October Meeting

Reported by R. W. Van Horne

The meeting was held at the Aero Club of B.C. at 20:00 hours on October 15th and was attended by 45 members and guests.

Since there was no Branch business requiring attention, a short intermission was declared prior to the introduction of our speakers.

The speakers for the evening, Mr. F. Watson of the New York office and Mr. R. Davies of the Toronto office, Shell Oil Co., were introduced by the Vice-Chairman, Mr. R. J. McWilliams.

Mr. Watson's subject was the problems of aviation fuel for piston engines and the necessity for rigid control of the lighter ends of gasoline in relation to the volatility required for easy starting of engines and the problem of evaporation to maintain these features. The heavier ends also constitute a problem in that dilution and incomplete combustion are direct results of an excess of these heavier ends. The problems of water absorption are very real and, because gasoline may absorb 200 parts per million at 100°F and only 2 parts per million at 50°F, it becomes apparent that the moisture and ice formation at screens and fuel pumps can be a problem as an aircraft climbs and the fuel becomes colder, allowing the absorbed moisture to precipitate out.

Mr. Watson also touched on the danger of skin contact with leaded fuel. Lead poisoning can result from this and, since it is an accumulative type of poisoning, caution should be used to avoid contact.

Mr. Davies' subject was fuels for jet and turbine powerplants, which create some new problems to the aviation fuel field. He traced the use of kerosene and the need to create a wider cut fuel to meet demand problems. The volatility of JP3 is in the same order as that of gasoline and has the same attendant problems. JP4 is a heavier fuel and has become more or less the standard for jet and turbine powerplants. It is easier to handle and allows greater climb rates without boiling in the tanks due to the heavier characteristics.

The talks were followed by a question and answer period and the interest of the group in the fuel problem was illustrated by the scope of the points raised.

Mr. C. E. B. McConachie thanked our speakers for a very informative and enlightening evening.

The meeting adjourned at 22:00 hours.

Montreal

Reported by F. M. Francis

Golf Tournament

The annual Golf Tournament of the Montreal Branch was held at St. Andrews Golf & Country Club on the 23rd August. The weather was excellent and a total of 108 members and guests played golf; 118 took advantage of the buffet dinner.

Mr. E. B. Schaefer was the winner of the Wright Trophy and Wedge with a gross score of 91. Mr. D. F. MacLaren, who also had a gross score of 91, lost the toss to Mr. Schaefer thereby losing the opportunity of remaining Tournament Champion, which he had been for three years running. Mr. W. Chester was the winner of the Ross Trophy, Miniature and Putter, with a gross score of 86. This trophy is competed for by the guests. Mr. R. Telford was the winner of a few practice balls with a high gross of 180.

The tournament was a complete success from start to finish and the buffet dinner was well catered and received with acclaim. I am sure that this is the answer to the dinner problem as players who finish early can proceed with their meal instead of waiting until everybody is ready to sit down.

Co-chairmen of the tournament arrangements were, as in past years, Mr. J. R. Chadborn and Mr. R. J. Conrath. Mr. H. A. Ross and Mr. T. W. Emerson rendered valuable assistance at the starter's table.

The prize winners are listed below:

Members

Bob Wright Memorial Trophy	E. B. Schaefer
Low Gross	D. F. MacLaren
Low Net	K. J. Grundy
2nd Low Gross	R. L. Hanson
2nd Low Gross	J. M. Schaffer
2nd Low Net	L. Rhodes
3rd Low Gross	A. Nicholls
3rd Low Net	D. P. Stowell
4th Low Gross	J. R. Holding
4th Low Gross	D. McDonald
4th Low Net	A. Schropfer
5th Low Gross	A. J. Lilly
5th Low Net	W. T. E. Jolliffe
6th Low Gross	W. W. McKenzie
6th Low Net	J. N. O'Connor
7th Low Gross	R. S. Cass
7th Low Net	J. S. Auston

Guests

Ross Aero Trophy	W. Chester
Low Net	W. Montgomery
2nd Low Gross	C. Saylor
2nd Low Net	G. Arnold
3rd Low Gross	M. Friedel
3rd Low Net	E. Shaw
4th Low Gross	J. Martin
4th Low Net	J. Egbert
5th Low Gross	A. Trottier
5th Low Net	G. Fields
6th Low Gross	H. Curtis
6th Low Net	R. McMillan

Miscellaneous

1st Hole Low	S. Levesque
2nd Hole High	V. V. McGorman
3rd Hole Low	C. Rhodes
5th Hole High	W. Wyley
7th Hole Low	W. P. Harris
9th Hole Low	G. McKinstry
High Gross	R. Telford

September Meeting

The meeting of the Montreal Branch, held on the 19th September with Mr. E. H. Higgins in the Chair, was addressed by Mr. R. H. Frost, President of the Stanley Aviation Corporation. Ninety-two members attended.

Mr. F. C. Phillips introduced Mr. Frost, who had chosen as his topic "The History of Pilot Escape Systems to the Present". After a few remarks concerning early development of escape systems, Mr. Frost described how the need for suitable escape means had been felt by the USAAF during World War 2. In 1943, 12½% of all attempted escapes from aircraft were fatal and 45% resulted in injury. In 1944, the corresponding figures had risen to 15% and 55% respectively. Despite these statistics, the USA did not do any development work during the war. The Germans, however, started on the problem in 1939 and, as a result, in 1944-45 both the Heinkel 162 and the ME 262 were equipped with ejection seats and approximately 60 successful ejections were made before the war's end. Mr. Frost described in detail the German development, which culminated in the success previously described and which established certain parameters which are valid to this day. The Germans discovered (a) a positive 20g vertical acceleration applied for 1/10th sec is a safe upper limit for a seated man, (b) the man and seat should be travelling between 200 and 250 ft/sec when leaving the airplane, (c) human blast tolerance is approximately 500 kts for 2 sec with the mouth and eyes closed, and (d) a ballistic cartridge appeared to be the most efficient means of obtaining correct acceleration and speed.

Mr. Frost paid tribute to Mr. James Martin of England who, unaware of German experiments, in 1944-45 successfully developed an ejection seat and came to the same set of conclusions built up by the Germans over a much longer period. Mr. Martin's seat was the first to apply a face curtain, which had the dual advantage of holding the spine erect and protecting the face of the ejectee from air blast.

In 1945, the USAF started work on escape systems largely on the German development basis. Again, the validity of the German figures was established and by August 1946 the first successful seat was produced to a USAF specification. In November of the same year, the US Navy also successfully produced a seat after working with the British firm of Martin Baker.

For the next few years, all developments in escape seats were along convergent lines, but even in 1948 and 1949 pilots were still most reluctant to eject in an emergency at high altitude or high airspeed. In 1949, an attempt was made to provide an automatic type unit utilizing 3 drogue chutes. This first attempt was soon modified by deletion of one chute and now consists primarily of the primary chute with an aneroid timer to separate seat and occupant at 13,000 ft. This seat is in service now and when properly used drops the escape fatality rate to 2%.

To complement newer aircraft coming along in the late 40's, work was commenced on the development of downward ejection seats. Although the escape velocity of such seats is approximately 60 ft/sec, the human negative g tolerance is only −10g per 1/10th sec. Correspondingly, different methods of support for the arms and legs are required because of the g force reversal. Late in 1952, the downward seat was debugged and it has been in service since that time.

The upper airspeed limit for ballistic cartridge-type ejection seats is in the vicinity of 550 mph. Beyond this speed, in the sonic and supersonic regions, fore and aft deceleration forces of approximately 30g are encountered and tumbling accelerations of 8,000 deg/sec have been measured. Windblast at M 1.0 at sea level appears to be beyond the upper limit for personal equipment and fabric shreds at this speed.

As a result, escape capsules are classed as mandatory equipment for all future USAF airplanes designed to fly faster than 600 kts or above 50,000 ft altitude.

Development of such capsules is being carried out by a number of different companies in the United States at the present time. The obvious advantages of capsules, such as pressurization, ability to float indefinitely and the inclusion of survival equipment and communication facilities, will be a big step forward in crew protection.

In the interim, the USAF have a number of airplane types operating or soon to be operative in the supersonic region. To provide adequate crew protection in these airplanes, an Industry Crew Escape Program Committee has been formed, with the major airframe manufacturers acting as coordinators. From this program, launched in September 1956, both Lockheed and Convair have come up with major advances in escape systems.

Irvine Culver of Lockheed applied stabilizing fins and a skip flow generator, similar to a bug deflector, to streamline the seat with shock waves. Convair have also been successful with their seat which tilts the occupant back 90° during ejection, thus protecting him from air blast. Both seats use rocket catapults and close attention is paid to c.g. position and L/D ratio.

At the conclusion of his talk, Mr. Frost showed films of model and full-scale tests for both the Lockheed and Convair seats. An interesting sidelight of the films was Mr. Frost's description of the elastic catapult method which is used for model tests. He stated that close correlation between model and full-scale tests had been achieved despite the primitive appearance of the catapult.

Mr. W. K. Ebel thanked the speaker on behalf of the Branch for his most interesting lecture.

Edmonton

Reported by C. Arnold

September Meeting

Mr. J. Portlock, Past Chairman, was in the Chair at the Edmonton Branch Dinner Meeting, which was held in the Corona Hotel on the 17th September. Some 60 members were present.

The meeting was addressed by Captain James Bell, Manager of the Edmonton Municipal Airport. He gave a most interesting talk on "Aviation Development in Edmonton and the North, 1927-1957". He was very well qualified to speak on this subject, having managed the Edmonton Airport since 1928.

He was thanked by Mr. C. C. Young, member of the Council.

(*A full account of Captain Bell's talk and, in fact, of the whole meeting was published in the September issue of the Northwest'ner, the house journal of Northwest Industries Limited. No purpose would be served by reproducing it here. We very much appreciate the interest shown by one of our Sustaining Members in giving such effective coverage to C.A.I. activities in their district. —Sec.*)

Cold Lake

Reported by F/L L. S. Lumsdaine

October Meeting

The Chairman, W/C R. D. H. Ellis, opened the meeting by welcoming the new members and guests and expressed regret at the departure of so many stalwart members from Avro and other firms connected with Project 'K'. He expressed satisfaction that the membership figure was still above 30 and hoped

that the Branch could now take stock in the knowledge that present members would remain during the winter and new members would fill the gaps.

W/C Ellis emphasized the growing importance and prestige of the C.A.I. in Canada and aviation circles generally and hoped that other members, in addition to himself and the Secretary, would be able to attend the Joint IAS/CAI Meeting during the month.

The Programme Chairman, S/L J. C. Olson, next outlined the plans for the winter and urged all members to complete a questionnaire to guide the Committee in planning the programme. A discussion followed in which it was decided to explore the possibility of obtaining lecturers to cover the following:

(1) The Britannia aircraft
(2) The Saskatchewan Air Ambulance Service
(3) Aircraft bush operations
(4) Supersonic flight problems
(5) Quality control
(6) Foreign objects in aircraft
(7) Cockpit instrumentation
(8) High-powered aircraft sound problems.

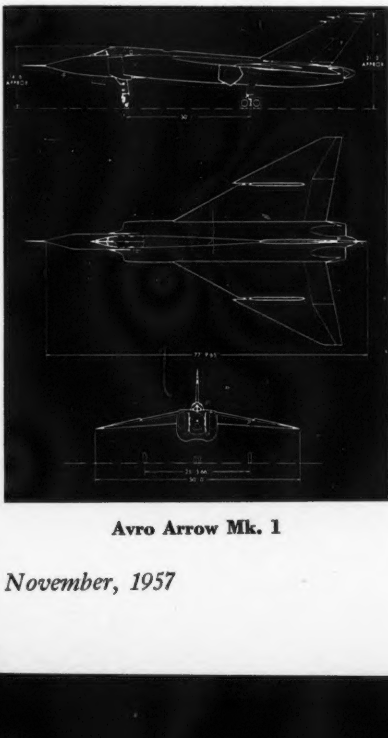
The film "Air Power '56", kindly loaned by CAE, was then shown to the meeting. This film showed the Bendix Trophy Race and the US National Air Show of last year.

Refreshments, further discussions and a final film on air power in 1943 completed a successful evening.

SUSTAINING MEMBERS

Avro Aircraft Ltd. unveiled its new supersonic fighter, the Arrow, at an impressive ceremony at Malton on the 4th October. The Honourable G. R. Pearkes, V.C., Minister of National Defence, was the guest of honour and some 1,500 other guests were present, in addition to the employees of the Company.

The unveiling ceremony represented the transfer of the prototype from the assembly line to flight test. It is expected to fly before the end of the year. The aircraft is a large twin-engined, two seater of delta configuration and of some 72,000 lb gross weight. The prototype, the Arrow 1, is powered by two Pratt & Whitney J75 engines; later on, the Arrow 2 will embody the Iroquois, built by Orenda Engines Ltd.



Avro Arrow Mk. 1

Canadian Applied Research Ltd. has announced that a licensing agreement has been effected with Transval Engineering Corp., Calif. This agreement licenses the Canadian aircraft instrumentation firm to produce certain airborne transistorized power supplies developed by Transval. The agreement provides for future broadening of the working relationship to include other products which the Canadian firm will handle. Transval produces a line of airborne radio equipment, transistorized power supplies, inverters and missile components.

Orenda Engines Ltd. has signed an agreement with the Curtiss-Wright Corporation covering the manufacture and development of the Iroquois engine in the USA. The agreement, which includes provisions for an exchange of technical information between the two organizations, is to run for 7 years. This is the first time a Canadian aero engine or aircraft company has concluded such an agreement with a US company.

Spartan Air Services Ltd., the air survey company of Ottawa, has been awarded two air photo-mapping contracts in the Caribbean area by the Colonial Survey of Great Britain.

The contracts cover the whole Island of Trinidad (approximately 1,900 sq mi) and upwards of 2,000 sq mi in British Guiana. The aircraft to be used is a Cessna 310, specially modified for vertical photography using the Swiss Wild RC-8 camera.

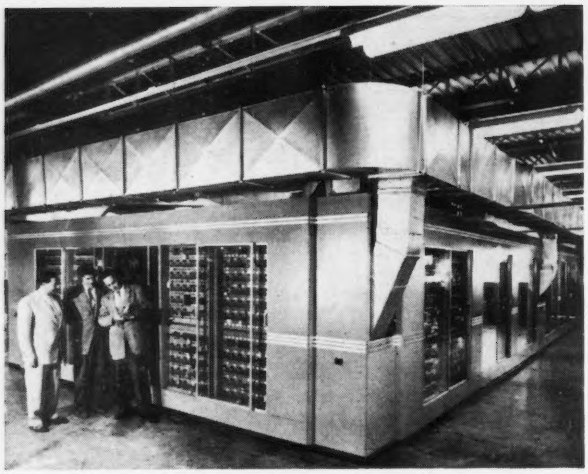
Computing Devices of Canada Ltd. have received a study contract in connection with their large computer to determine whether it can be effectively applied to complex problems of air traffic control. The study is under the supervision of the Department of Transport in cooperation with the United States Civil Aeronautics Administration which requires a large-scale air traffic control simulator for operations analysis.

Upon completion of the study, if it is decided that the equipment is to be adapted as an air traffic control simulator, it will be leased to the CAA. The DOT's Air Services will have full access to all the studies carried out and, in addition, will also avail itself of the simulator for periods each year for its own investigations.

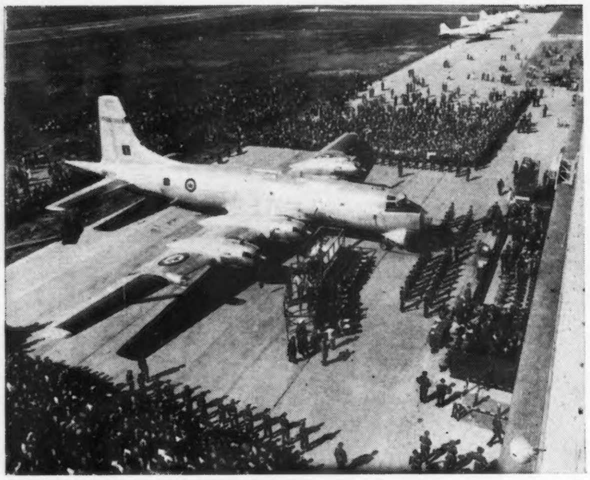
Increasingly heavy traffic at major airports involving high speed jet aircraft have posed serious problems in air traffic control. The use of a simulator will make it possible to test new traffic patterns, communication and navigation systems without the cost and risk of using actual aircraft.

It is intended that approximately 100 aircraft will be simulated in the equipment simultaneously when modified for air traffic control studies. As well as simulating the movements of aircraft as directed by air traffic controllers, it will provide simulated radar plots, communication channels and other facilities presently in use or planned at major airports.

Originally designed as a part of a tactical trainer, the central computer has more than 6,000 electronic tubes, arranged in 17 sections and occupying a



CDC's large computer



Canadair Argus

floor space of 23 x 50 ft. Heart of the machine is a "position memory" which automatically computes future positions of all craft under study.

The CAA was of the opinion that adaptation of the Canadian development would save it considerable money and 3 years of developmental time. It was expected that the joint approach by the DOT and the CAA to the problem of air traffic control in the future would be materially aided.

Canadair Ltd. handed over the first Argus to the RCAF at a christening and acceptance ceremony staged on the 30th September. The christening was performed by Mrs. Campbell, wife of Air Marshal Campbell, C.A.S., who broke a bottle of champagne on the nose of the aircraft. The aircraft, the biggest ever built in Canada, was then formally accepted by the Honourable G. R. Pearkes, V.C., Minister of National Defence. Over 9,000 people were present.

SUSTAINING MEMBERS

of the

CANADIAN AERONAUTICAL INSTITUTE

1957-58

Aeroquip (Canada) Limited

Aircraft Industries of Canada Limited

Air-ex Incorporated

Alloy Metal Sales Limited

Aviation Electric Limited

Avro Aircraft Limited

Babb Company (Canada) Limited

Bristol Aero Engines Limited

Bristol Aero Engines (Western) Limited

Bristol Aeroplane Company of Canada (1956) Limited

Bristol Aircraft (Western) Limited

B. W. Deane & Company

Campbellford Precision Products Limited

Canadair Limited

Canadian Applied Research Limited

Canadian Car Company Limited

Canadian Pacific Air Lines Limited

Canadian Pratt & Whitney Aircraft Company Limited

Canadian Steel Improvement Limited

Canadian Westinghouse Company Limited

Cannon Electric Canada Limited

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Collins Radio Company of Canada Limited

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Decca Navigator (Canada) Limited

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Honeywell Controls Limited

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Jarry Hydraulics

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Prenco Progress & Engineering Corporation Limited

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S. Smith & Sons (Canada) Limited

Spartan Air Services Limited

Standard Aero Engine Limited

Thompson Products Limited

Trans-Canada Air Lines

Walter Kidde & Company Limited

York Gears Limited

SPECIALIST SECTIONS

The structure of the Canadian Aeronautical Institute provides for the formation of Sections devoted to special fields of aeronautical work. Each Section is, in effect, a specialist society, operating within the framework of the Institute and using the Institute's facilities.

A Section is similar to a Branch in that it is administered by an Executive Committee which is elected by the members of the Section. The essential difference between the two lies in the qualifications for membership; a member of a Branch must live in the area served by the Branch, whereas a member of a Section must possess technical qualifications appropriate to the field served by the Section. Members of the C.A.I. may belong to as many Sections as they wish, provided they possess the necessary qualifications, at no additional cost in the form of dues etc.

A Test Pilots Section was formed in November 1956 and steps are now being taken to form a Propulsion Section.

Any other groups of specialists who wish to promote the formation of Sections, in which they can further their own technical interests, should get in touch with

The Secretary
Canadian Aeronautical Institute
Commonwealth Building
77 Metcalfe Street
Ottawa, Ontario.

MEMBERSHIP OF THE C.A.I.

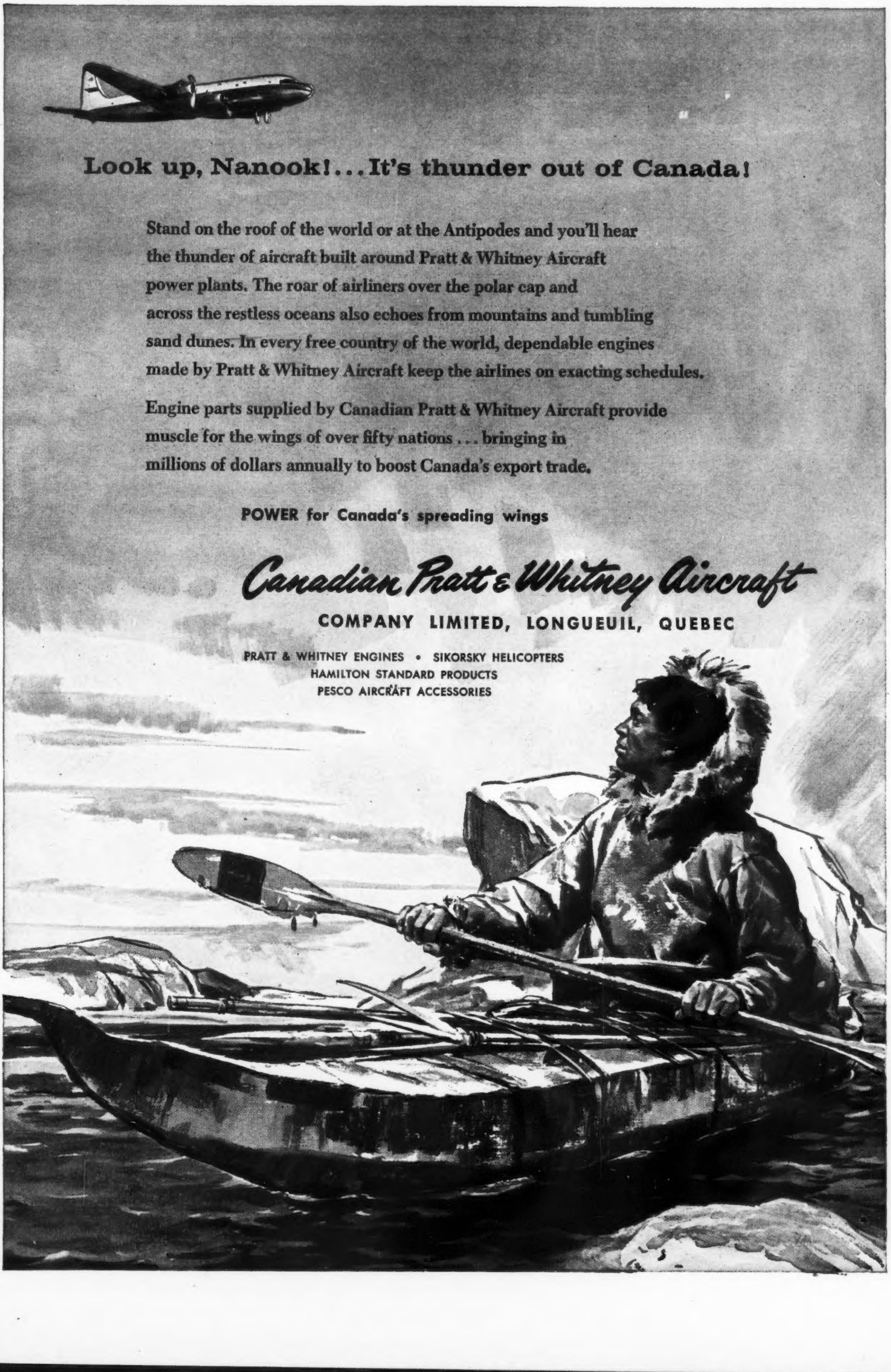
The qualifications and annual dues set out in the table below are those presently laid down by the By-laws. The rates of dues shown in brackets are those applicable to members who are also members of the R.Ae.S., I.A.S. or E.I.C. or who are resident outside Canada or the U.S.A.

The annual dues include a non-deductible subscription to the *Canadian Aeronautical Journal.*

Applications for membership must be made on the approved forms, which may be procured from the Secretaries of the Branches or from C.A.I. Headquarters. An applicant does not apply for membership in any particular grade, but each application is considered by the Admissions Committee and by the Council, who decide the grade suitable to the applicant's qualifications. On admission, the applicant is informed of his grading and the appropriate entrance fee and annual dues.

The entrance fee is $5.00, except in certain special circumstances.

Grade	Qualifications	Annual Dues
Student	Undergoing a course of study at an approved school of engineering or technology	$3.00 ($2.00)
Technician	Engaged in technical work in aviation	$5.00 ($2.00)
Technical Member	Engaged in science, engineering, research, manufacture or operation, in aeronautics or related fields, for 4 years or graduated from an approved school of engineering or science	$7.00 ($4.00)
Member	Engaged in aviation for 8 years and acquired a recognized standing	$8.00 ($4.00)
Associate	Engaged in aviation, though not qualified for technical grades	$8.00 ($4.00)
Associate Fellow	Engaged in aeronautical science or engineering for 10 years and been in responsible charge or made outstanding contribution	$9.00 ($5.00)
Fellow	Been an Associate Fellow for 1 year and attained distinction in aeronautics	$10.00 ($5.00)


Look up, Nanook!...It's thunder out of Canada!
Stand on the roof of the world or at the Antipodes and you'll hear the thunder of aircraft built around Pratt & Whitney Aircraft power plants. The roar of airliners over the polar cap and across the restless oceans also echoes from mountains and tumbling sand dunes. In every free country of the world, dependable engines made by Pratt & Whitney Aircraft keep the airlines on exacting schedules.
Engine parts supplied by Canadian Pratt & Whitney Aircraft provide muscle for the wings of over fifty nations ... bringing in millions of dollars annually to boost Canada's export trade.
POWER for Canada's spreading wings
Canadian Pratt & Whitney Aircraft
COMPANY LIMITED, LONGUEUIL, QUEBEC
PRATT & WHITNEY ENGINES • SIKORSKY HELICOPTERS
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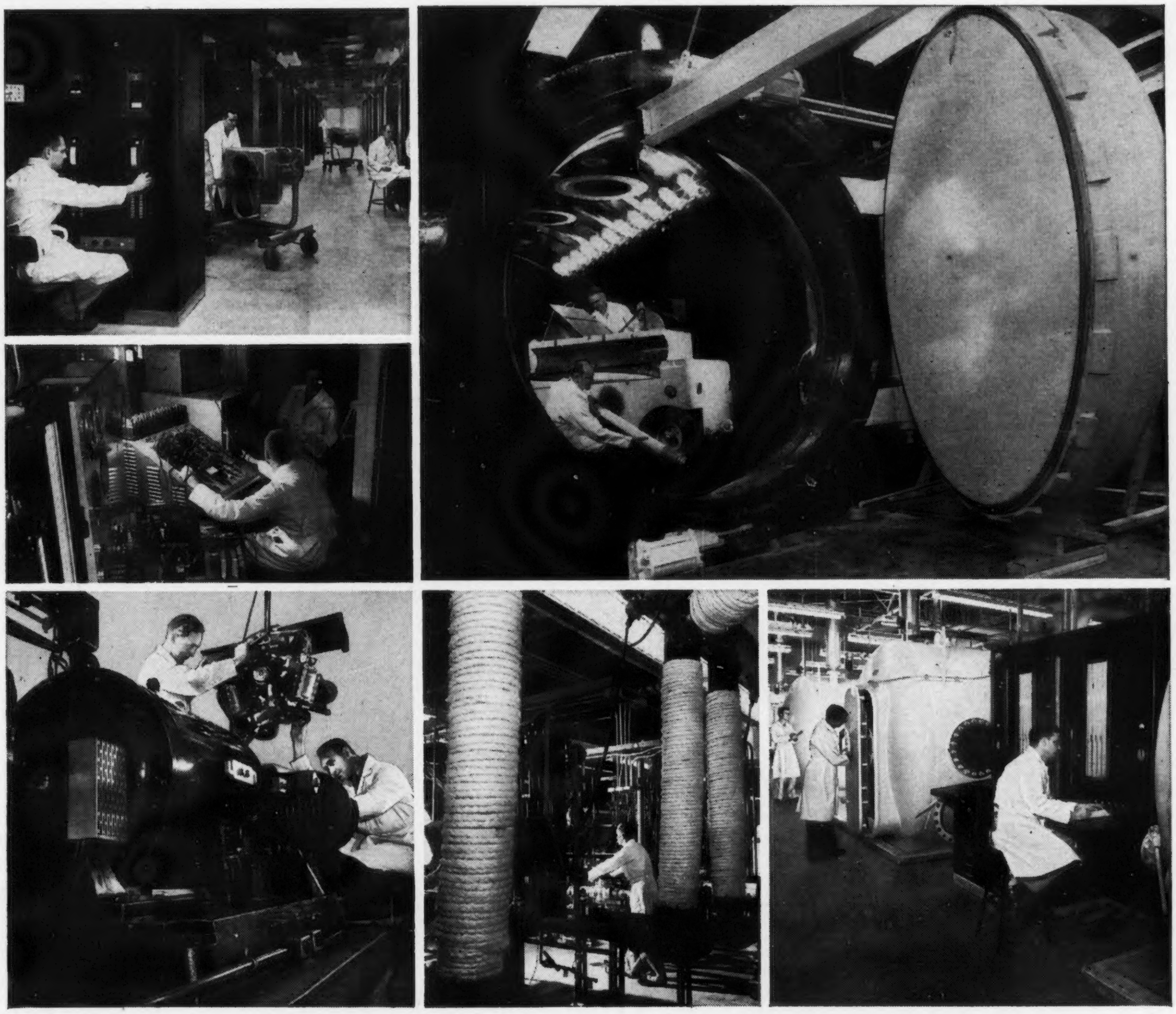
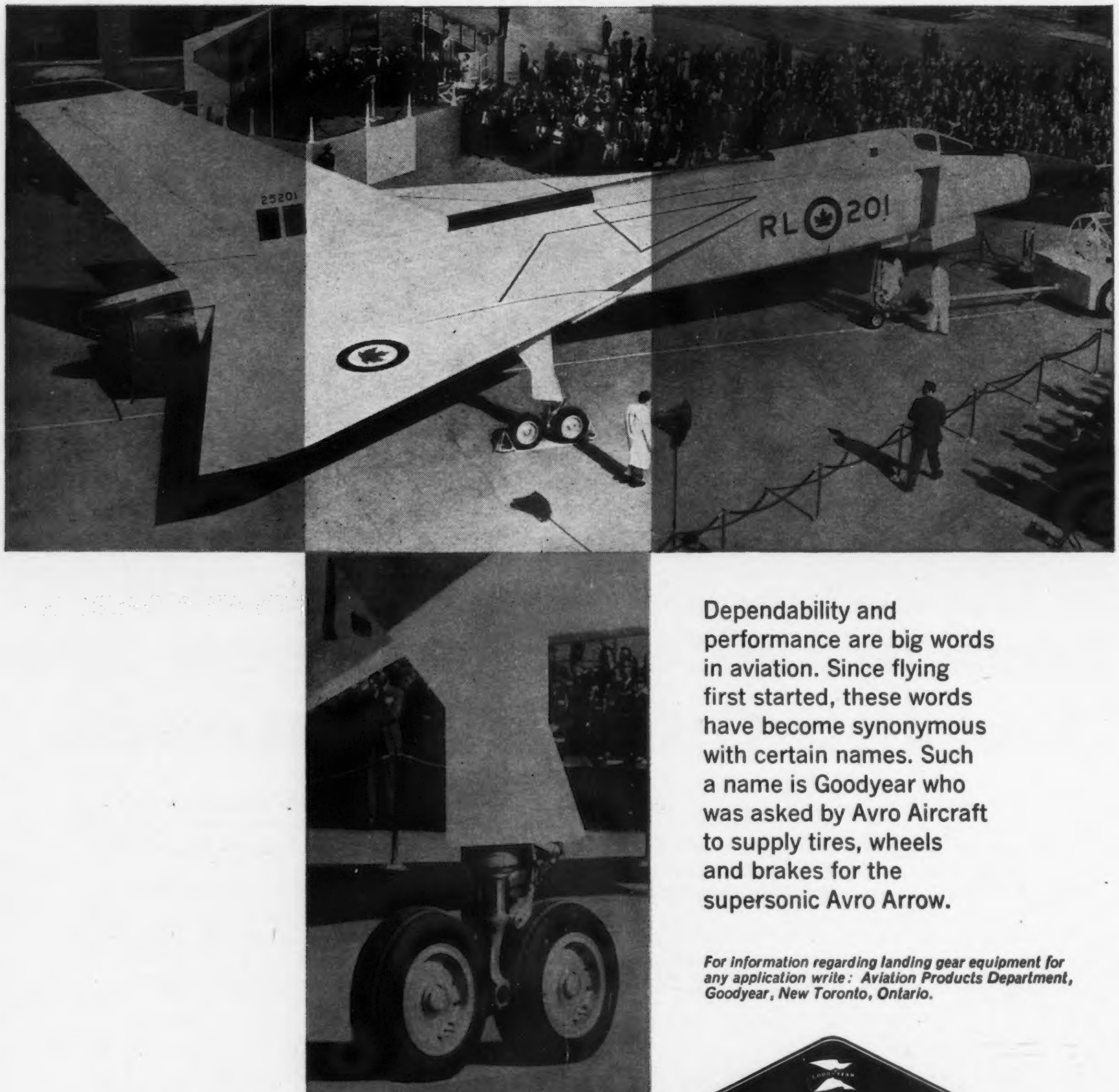


Avro Arrow

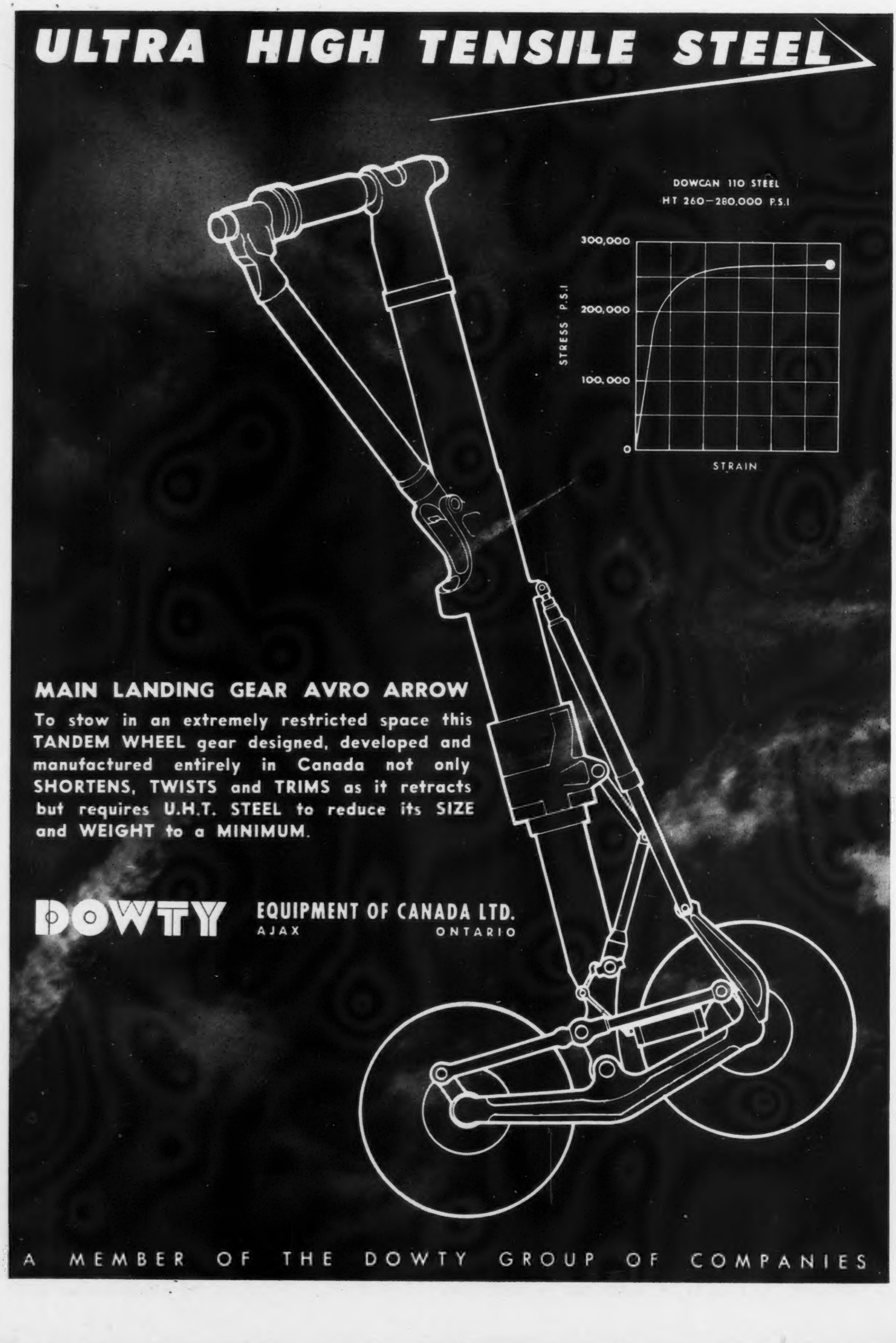
...equipped with Goodyear tires, wheels and brakes... has the best in the world at its "feet"



Dependability and performance are big words in aviation. Since flying first started, these words have become synonymous with certain names. Such a name is Goodyear who was asked by Avro Aircraft to supply tires, wheels and brakes for the supersonic Avro Arrow.

For information regarding landing gear equipment for any application write: Aviation Products Department, Goodyear, New Toronto, Ontario.

GOODYEAR
AVIATION
PRODUCTS


ULTRA HIGH TENSILE STEEL
DOWCAN 110 STEEL
HT 260—280,000 P.S.I
300,000
200,000
100,000
0
STRESS P.S.I
STRAIN
MAIN LANDING GEAR AVRO ARROW
To stow in an extremely restricted space this TANDEM WHEEL gear designed, developed and manufactured entirely in Canada not only SHORTENS, TWISTS and TRIMS as it retracts but requires U.H.T. STEEL to reduce its SIZE and WEIGHT to a MINIMUM.
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